



RESEARCH MEMORANDUM

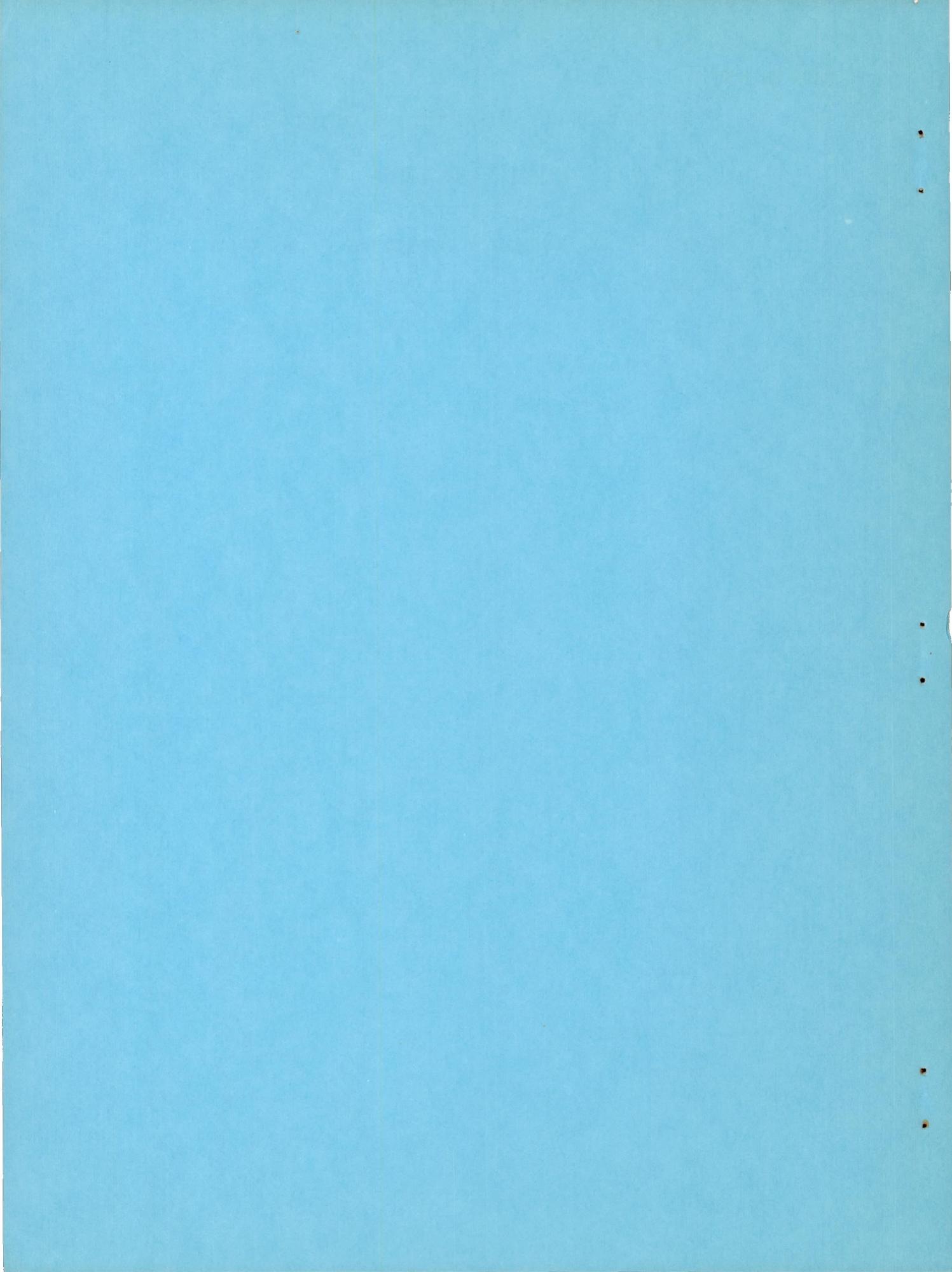
EFFECTS OF SYSTEMATICALLY VARYING THE SPANWISE AND
VERTICAL LOCATION OF AN EXTERNAL STORE ON THE
AERODYNAMIC CHARACTERISTICS OF AN UNSWEPT
TAPERED WING OF ASPECT RATIO 4 AT MACH
NUMBERS OF 1.41, 1.62, AND 1.96

By Carl R. Jacobsen

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON

August 20, 1952
Declassified June 24, 1958



NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

EFFECTS OF SYSTEMATICALLY VARYING THE SPANWISE AND
VERTICAL LOCATION OF AN EXTERNAL STORE ON THE
AERODYNAMIC CHARACTERISTICS OF AN UNSWEPT
TAPERED WING OF ASPECT RATIO 4 AT MACH
NUMBERS OF 1.41, 1.62, AND 1.96

By Carl R. Jacobsen

SUMMARY

An investigation has been made in the Langley 9- by 12-inch supersonic blowdown tunnel to determine the effects of an external store on the lift, drag, and pitching-moment characteristics of an unswept wing of aspect ratio 4 at Mach numbers of 1.41, 1.62, and 1.96. The spanwise and vertical location of a Douglas Aircraft Company, Inc., store of fineness ratio 8.58 was systematically varied over the outer 60 percent of the wing semispan. Brief comparative tests were made to determine the effects of changing the store shape to an NACA 65A body of revolution with the same fineness ratio, of changing the chordwise location of the strut attaching the store to the wing, and of doubling the strut chord. Wing Reynolds number ranged from 1.1×10^6 to 1.4×10^6 .

INTRODUCTION

External stores have been used to advantage in carrying fuel and ordnance on aircraft and a fairly large amount of information is available concerning their aerodynamic influence on wing characteristics at subsonic and transonic speeds (for example, see refs. 1 to 8). It is desirable to know whether stores can still be used advantageously at supersonic speeds, but little information is available since the few experimental investigations to date (refs. 9 to 11) have been quite limited in scope. Consequently, in order to obtain comprehensive experimental information at supersonic speeds, an exploratory program has been initiated in the Langley 9- by 12-inch supersonic blowdown

tunnel to study effects of stores on the characteristics of several wing configurations.

This paper contains data obtained for one external store on an unswept wing which had an aspect ratio of 4, a taper ratio of 0.6, and airfoil sections of a thickness of 4 percent. The store had a fineness ratio of 8.58 and a Douglas Aircraft Company, Inc., store shape. For a wing area of 500 square feet, the store would have sufficient volume to contain about 400 gallons of fuel. The spanwise and vertical store locations were systematically varied on the outboard 60 percent of the semispan at Mach numbers of 1.41, 1.62, and 1.96 and at wing lift coefficients up to 0.80. Also included are the results of a brief investigation of store shape, strut-chord length, and strut chordwise location. The Reynolds number based on wing chord ranged from 1.1×10^6 to 1.4×10^6 . The data are presented without analysis to expedite publication.

COEFFICIENTS AND SYMBOLS

C_L lift coefficient $\left(\frac{\text{Lift}}{qS} \right)$

C_D drag coefficient $\left(\frac{\text{Drag}}{qS} \right)$

C_m pitching-moment coefficient $\left(\frac{\text{Pitching moment about } 0.25\bar{c}}{qS\bar{c}} \right)$

$\frac{dC_m}{dC_L}$ rate of change of pitching-moment coefficient with lift coefficient

ΔC_m increment in wing pitching-moment coefficient caused by addition of external store

ΔC_D increment in drag coefficient due to addition of external store

q free-stream dynamic pressure

S semispan wing area (9.0 square inches)

c wing chord

\bar{c} mean aerodynamic chord

b	wing span, twice distance from wing root chord to wing tip
y	spanwise distance from wing root chord to store center line
z	vertical distance from point of maximum thickness on wing lower surface to store center line
d	store diameter
l	store length
α	angle of attack
$\Delta\alpha$	increment in wing angle of attack due to addition of external store
R	Reynolds number based on \bar{c}

MODELS

The principal dimensions of the semispan wing which had an aspect ratio of 4 and a taper ratio of 0.6 are contained in figure 1. The sections perpendicular to the unswept quarter-chord line were NACA 65A004 airfoil sections. The blunt streamwise wing tip was not faired. The solid wing was fabricated from SAE 4130 heat-treated steel.

External stores having the Douglas Aircraft Company (DAC) store shape of fineness ratio 8.58 were tested at 40, 60, 80, 99, and 105 percent of the wing semispan (fig. 2). In all cases the store 40-percent length point was located at the quarter-chord point of the wing. The stores were molded of plastic and were designed to have a gross volume of 414 gallons for a wing area of 500 square feet.

Unswept struts which were pinned and sweated to the wing surface were used to attach the stores to the wing at various vertical store locations. The brass struts had NACA 65A airfoil sections. The basic strut had a chord equal to $0.514\bar{c}$ and was 10-percent thick. The configuration for which the leading edge of this strut was located at the wing leading edge is designated as the basic strut configuration. Two additional strut configurations were tested at the 40-percent spanwise station: For one configuration, the leading edge of the basic strut was moved back to the 25-percent chord station so that the midchords of strut and wing were coincident; and for the other configuration, the basic strut was doubled in chord and thinned to a 3.5-percent-thick airfoil section (with approximately the same bending strength as the basic strut). The doubled strut chord was equal to the wing chord at the 40-percent spanwise station.

An NACA 65A body of revolution having the same volume, fineness ratio, and location of the 40-percent length point as the Douglas store shape was also tested on the basic strut at the 40-percent spanwise station. The center lines of all stores were within 1° of being parallel to the rolling-moment axis.

TUNNEL

The Langley 9- by 12-inch supersonic blowdown tunnel in which the present tests were made uses the compressed air of the Langley 19-foot pressure tunnel. The air enters at an absolute pressure of about $2\frac{1}{3}$ atmospheres, is conditioned to insure condensation-free flow by being passed through a silica gel dryer and then through finned banks of electrical heaters. The criteria for the amount of drying and heating required were obtained from reference 12. Extensive calibration measurements had been made previously with no model in the test section. A summary of the results of these tests is contained in reference 13 and is as follows:

Variables	Average Mach number	1.41	1.62	1.96
Maximum deviation in Mach number	± 0.02	± 0.01	± 0.02	
Maximum deviation of static to stagnation pressure, percent	± 2.0	± 1.3	± 2.2	
Maximum deviation in stream angle, deg	± 0.25	± 0.20	± 0.20	
Average dynamic pressure for these tests, pound per square inch	12.0	11.4	10.2	
Average Reynolds number, $R \times 10^{-6}$	1.4	1.2	1.1	

The test Reynolds number decreased about 3 percent during the course of each run because of the decreasing pressure of the inlet air.

TEST TECHNIQUE

The semispan wing model used in this investigation was cantilevered from a strain-gage balance which mounts flush with the tunnel wall and rotates with the model through the angle-of-attack range. A half-fuselage which consisted of a half-body of revolution and a 0.25-inch shim was attached to the wing, and loads were measured on both the wing

and fuselage. The half-body was shimmed away from the tunnel wall to minimize the effects of the tunnel-wall boundary layer on the flow over the body (ref. 14). A gap of about 0.010 inch was maintained between the fuselage and tunnel wall under a no-load condition. The investigation was made at Mach numbers of 1.41, 1.62, and 1.96 and at wing lift coefficients up to 0.80. There was some indication that at a Mach number of 1.41 the data of the present investigation might have been influenced by the reflection of the model bow wave from the tunnel wall at an angle of attack equal to 12° .

ACCURACY OF DATA

From a general consideration of the balance-calibration accuracy and the repeatability of data, the accuracy of the force and moment measurements, in terms of coefficients, are believed to be about as follows:

For lift coefficients above 0.5 to 0.6, errors in drag coefficient in excess of ± 0.001 could well exist.

RESULTS

Lift, pitching-moment, and drag data are presented without analysis for the wing-fuselage-store combinations, for the wing-fuselage combination, and for the fuselage alone. Figure 3 presents the variations of lift, pitching moment, and drag coefficient with angle of attack at Mach numbers of 1.41, 1.62, and 1.96 for the fuselage alone. Figures 4 to 12 present the variations of pitching-moment coefficient, angle of attack, and drag coefficient with lift coefficient for the wing-fuselage-store combinations at the same three Mach numbers. The scales for the drag plots have been staggered to illustrate more clearly the variations with lift coefficient. From these data, values of $\frac{dC_m}{dC_L}$ and increments of pitching-moment coefficient and angle of attack at zero lift due to the addition of the store have been obtained and are presented in figure 13. It might be pointed out that positive increments in pitching moment at zero lift caused by the store as shown in figure 13 were also obtained in the investigation of reference 10. The

variations of the lift-drag ratios with lift coefficient for the various store locations have also been obtained and are presented in figure 14 along with the drag increments caused by the addition of the store. Similar summary plots are presented in figure 15 to show the effects of store shape, strut-chord length, and strut chordwise location.

From the data of figure 15, it is evident that the basic strut configuration was not optimum with regard to drag. It is believed, however, that the general trends shown for the basic configuration (decreasing drag with outboard spanwise movement of the store on the wing) would not be affected to any sizable degree by the use of other unswept strut configurations.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va.

REFERENCES

1. Muse, T. C., and Radey, K.: Aerodynamic Characteristics of Several External Store Installations on a Swept-Wing Hypothetical Bomber. Rep. No. ES-15456, Douglas Aircraft Co., Inc., Aug. 16, 1950.
2. Tamburello, V., and Burgan, Elmer: Exploratory Wind-Tunnel Tests of External Stores Mounted in Various Locations on the Wing of a 0.17-Scale Model Jet-Fighter Type Airplane. Rep. C-453 Aero. 806, David W. Taylor Model Basin, Navy Dept., Sept. 1951.
3. Spreeman, Kenneth P., and Alford, William J., Jr.: Investigation of the Effects of Geometric Changes in an Underwing Pylon-Suspended External-Store Installation on the Aerodynamic Characteristics of a 45° Sweptback Wing at High Subsonic Speeds. NACA RM L50L12, 1951.
4. Silvers, H. Norman, King, Thomas J., Jr., and Pasteur, Thomas B., Jr.: Investigation of the Effect of a Nacelle at Various Chordwise and Vertical Positions on the Aerodynamic Characteristics at High Subsonic Speeds of a 45° Sweptback Wing With and Without a Fuselage. NACA RM L51H16, 1951.
5. Alexander, Sidney R.: Effect of Strut-Mounted Wing Tanks on the Drag of NACA RM-2 Test Vehicles in Flight at Transonic Speeds. NACA RM L8H31a, 1948.
6. Pepper, William B., Jr., and Hoffman, Sherwood: Transonic Flight Tests To Compare the Zero-Lift Drag of Underslung and Symmetrical Nacelles Varied Chordwise at 40 Percent Semispan of a 45° Sweptback, Tapered Wing. NACA RM L50G17a, 1950.
7. Welsh, Clement J., and Morrow, John D.: Effect of Wing-Tank Location on the Drag and Trim of a Swept-Wing Model as Measured in Flight at Transonic Speeds. NACA RM L50A19, 1950.
8. Hoffman, Sherwood, and Mapp, Richard C., Jr.: Transonic Flight Tests To Compare the Zero-Lift Drags of 45° Sweptback Wings of Aspect Ratio 3.55 and 6.0 With and Without Nacelles at the Wing Tips. NACA RM L51L27, 1952.
9. Madden, Robert T., and Kremzier, Emil J.: Data Presentation of Force Characteristics of Several Engine-Strut-Body Configurations at Mach Numbers of 1.8 and 2.0. NACA RM E51E29, 1951.

10. Hasel, Lowell E., and Sevier, John R., Jr.: Aerodynamic Characteristics at Supersonic Speeds of a Series of Wing-Body Combinations Having Cambered Wings With an Aspect Ratio of 3.5 and a Taper Ratio of 0.2. Effect at $M = 1.60$ of Nacelle Shape and Position on the Aerodynamic Characteristics in Pitch of Two Wing-Body Combinations With 47° Sweptback Wings. NACA RM L51K14a, 1952.
11. May, Ellery B., Jr.: Investigation of the Aerodynamic Effects of an External Store in Combination With 60° Delta and Low-Aspect-Ratio Tapered Wings at a Mach Number of 1.9. NACA RM L50K03, 1951.
12. Burgess, Warren C., Jr., and Seashore, Ferris L.: Criterions for Condensation-Free Flow in Supersonic Tunnels. NACA TN 2518, 1951.
13. May, Ellery B., Jr.: Investigation of the Effects of Leading-Edge Chord-Extensions on the Aerodynamic and Control Characteristics of Two Sweptback Wings at Mach Numbers of 1.41, 1.62, and 1.96. NACA RM L50L06a, 1951.
14. Conner, D. William: Aerodynamic Characteristics of Two All-Movable Wings Tested in the Presence of a Fuselage at a Mach Number of 1.9. NACA RM L8H04, 1948.

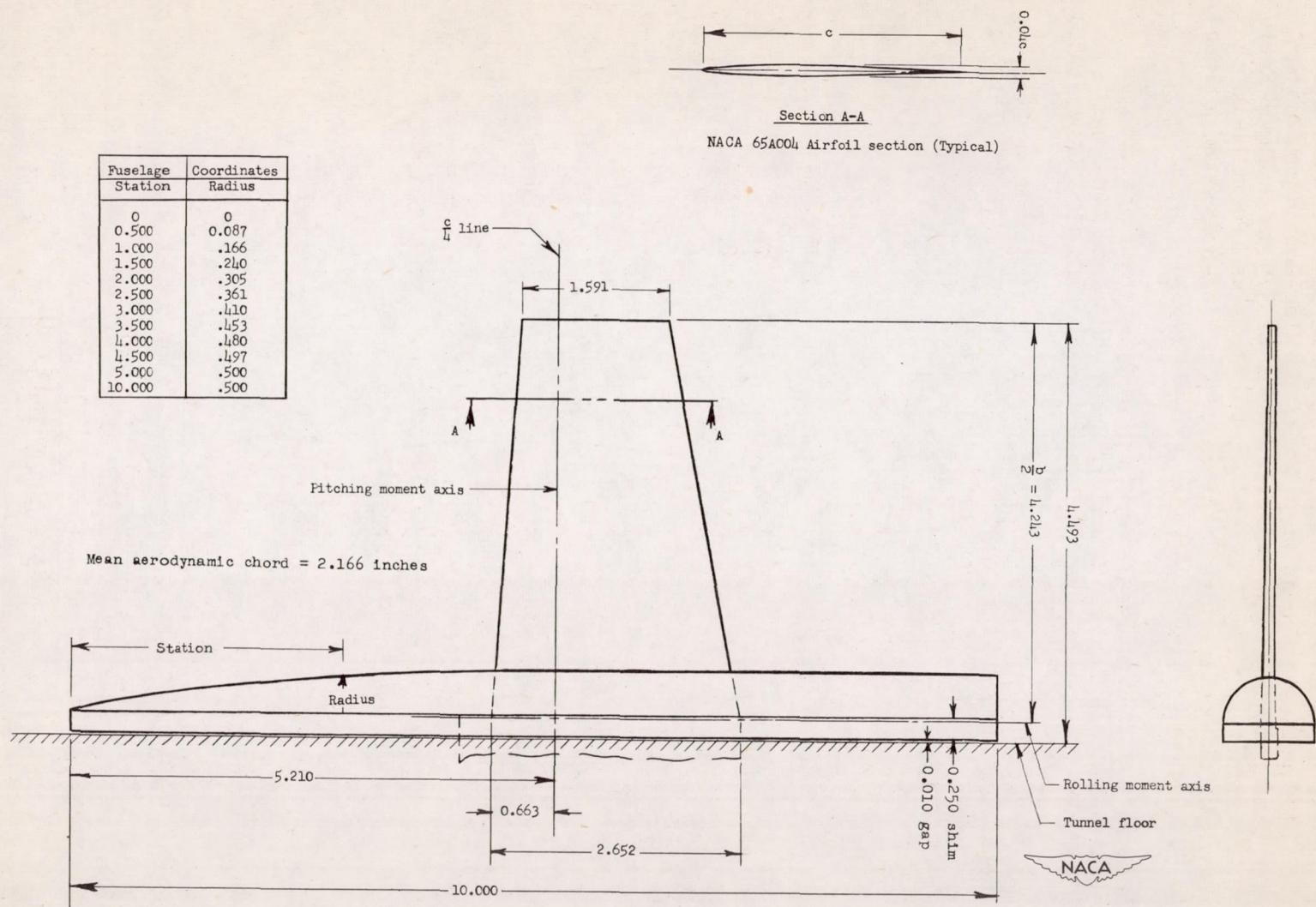


Figure 1.- Details of unswept semispan wing of aspect ratio 4. (All dimensions are in inches.)

DAC Store Coordinates		65A Store Coordinates	
x	y	x	y
0	0	0	0
0.076	.036	0.021	0.036
.188	.080	.031	.044
.299	.116	.052	.057
.411	.140	.206	.104
.519	.160	.412	.146
.630	.176	.618	.174
.742	.188	.824	.198
.966	.211	1.235	.227
1.185	.227	1.647	.239
1.408	.233	2.059	.232
1.983	.233	2.471	.205
2.206	.229	2.882	.163
2.426	.219	3.294	.112
2.645	.203	3.706	.057
2.873	.184	4.118	.001
3.204	.148	L.E.R.	.036
3.423	.120		
3.647	.088		
3.910	.048		
3.990	0		
T.E.R.	.022		

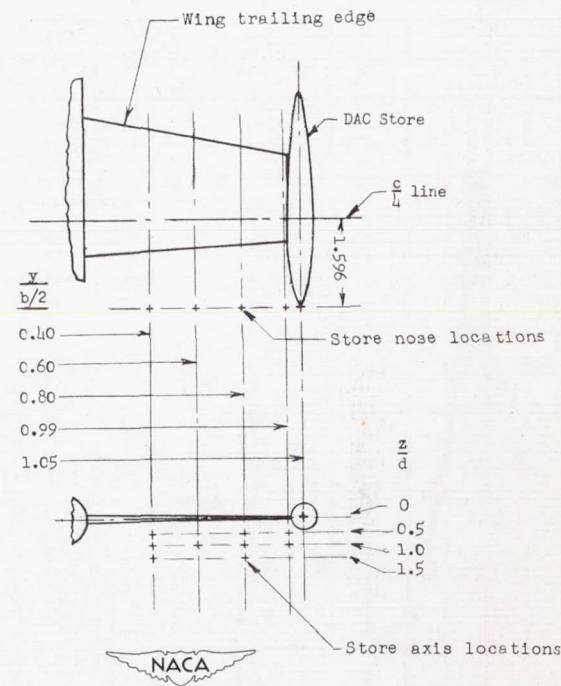
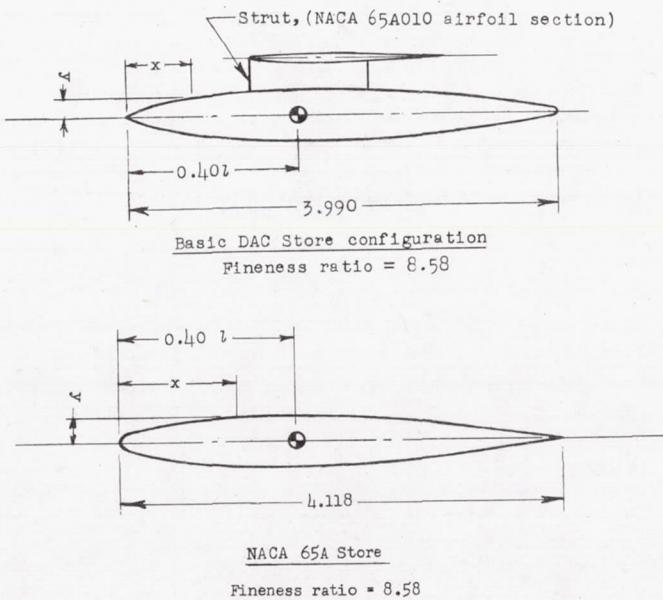


Figure 2.- Details of Douglas Aircraft Company store and NACA 65A-series body of revolution. (All dimensions are in inches.)

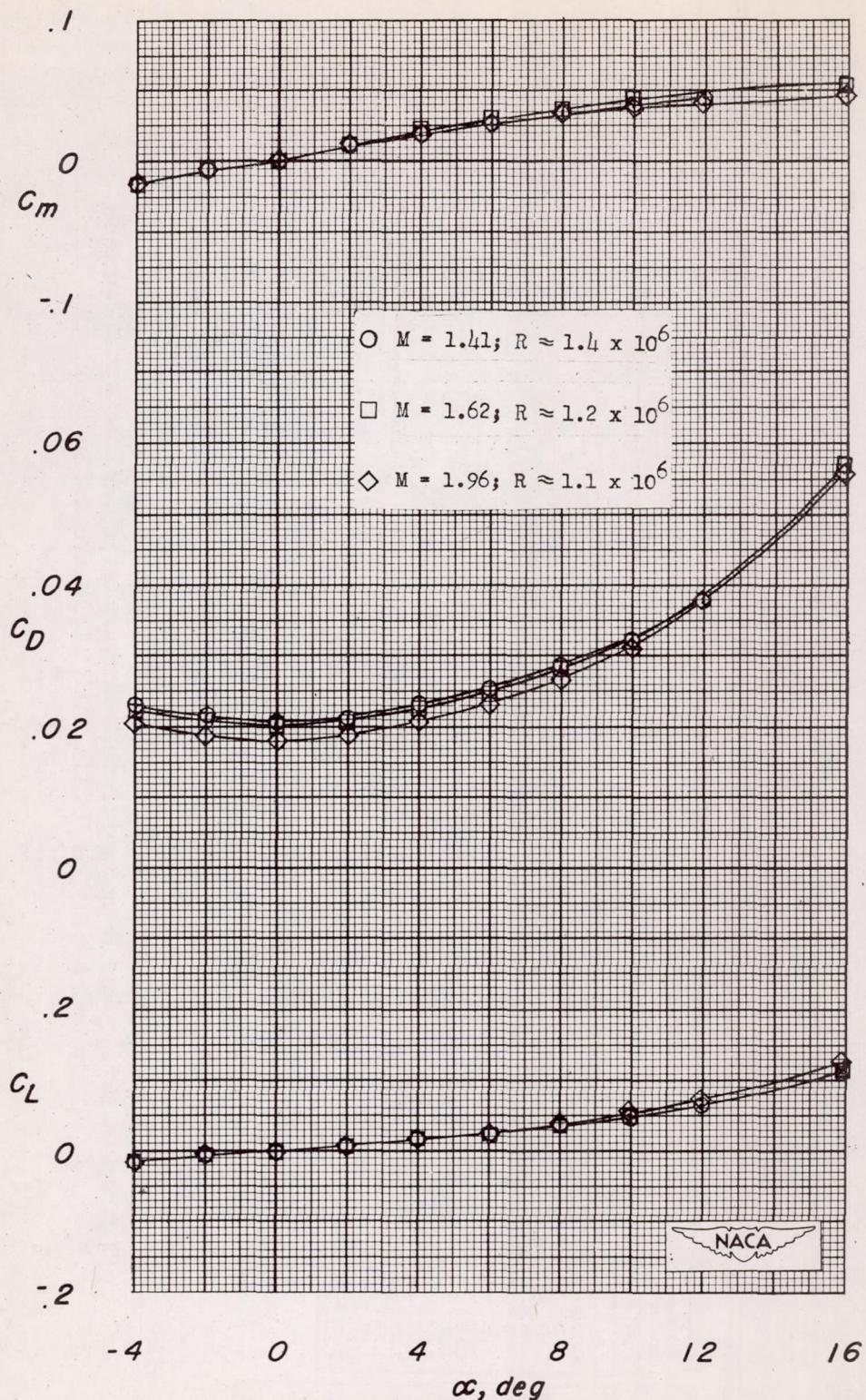


Figure 3.- Aerodynamic characteristics of the half-fuselage without the unswept wing.

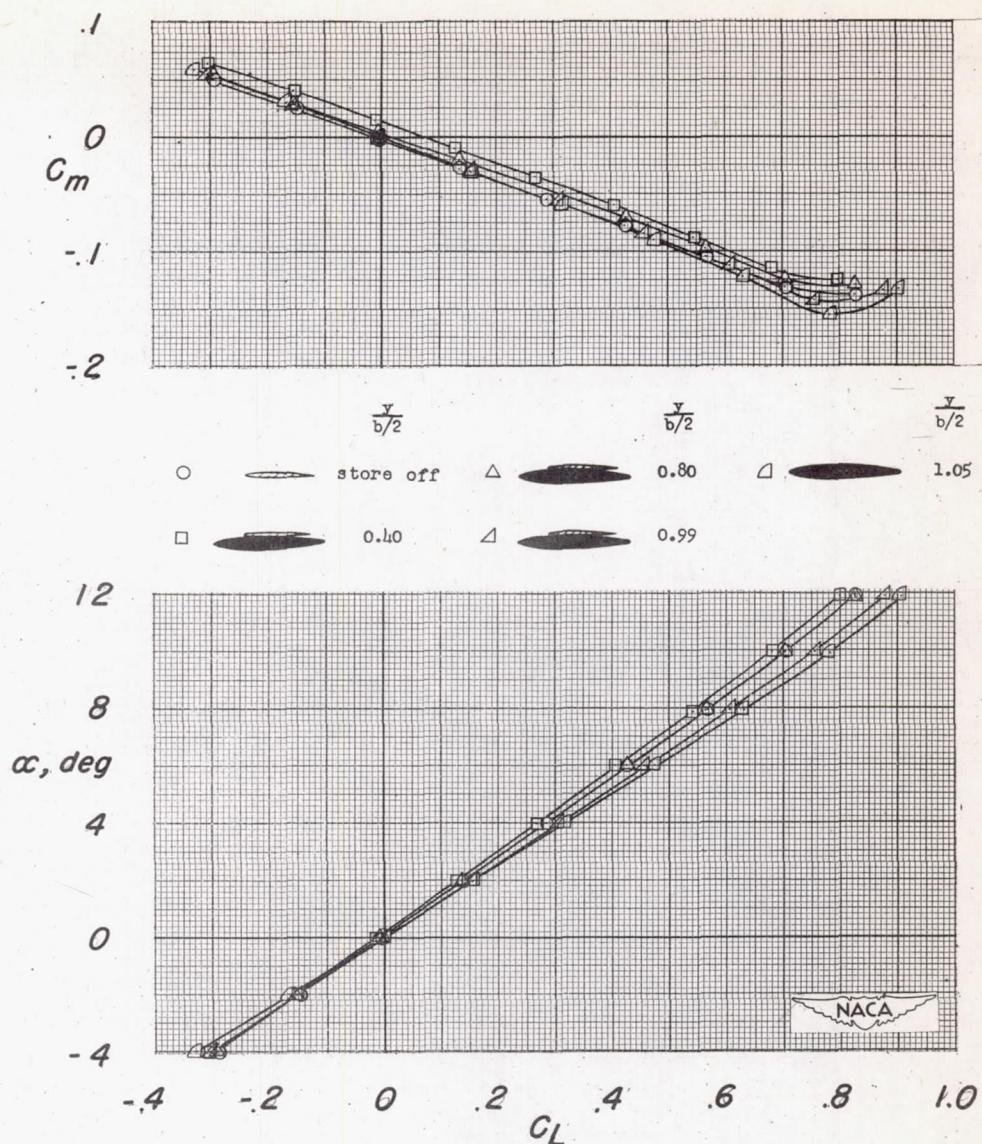
(a) C_m and α against C_L .

Figure 4.- Aerodynamic characteristics of an unswept semispan wing of aspect ratio 4 with DAC store with basic strut at various spanwise locations. $M = 1.41$; $R \approx 1.4 \times 10^6$; $\frac{z}{d} = 0$ and 0.5 .

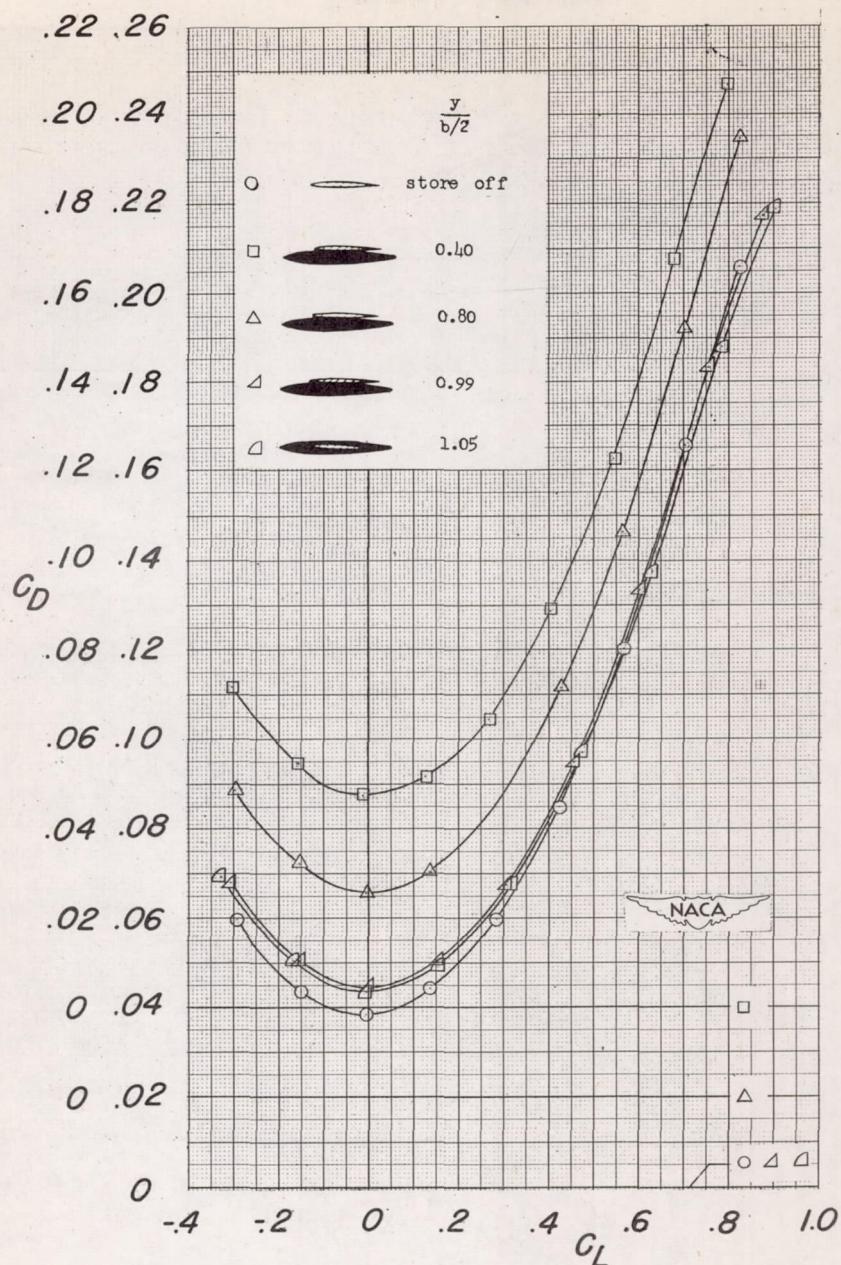
(b) C_D against C_L .

Figure 4.- Concluded.

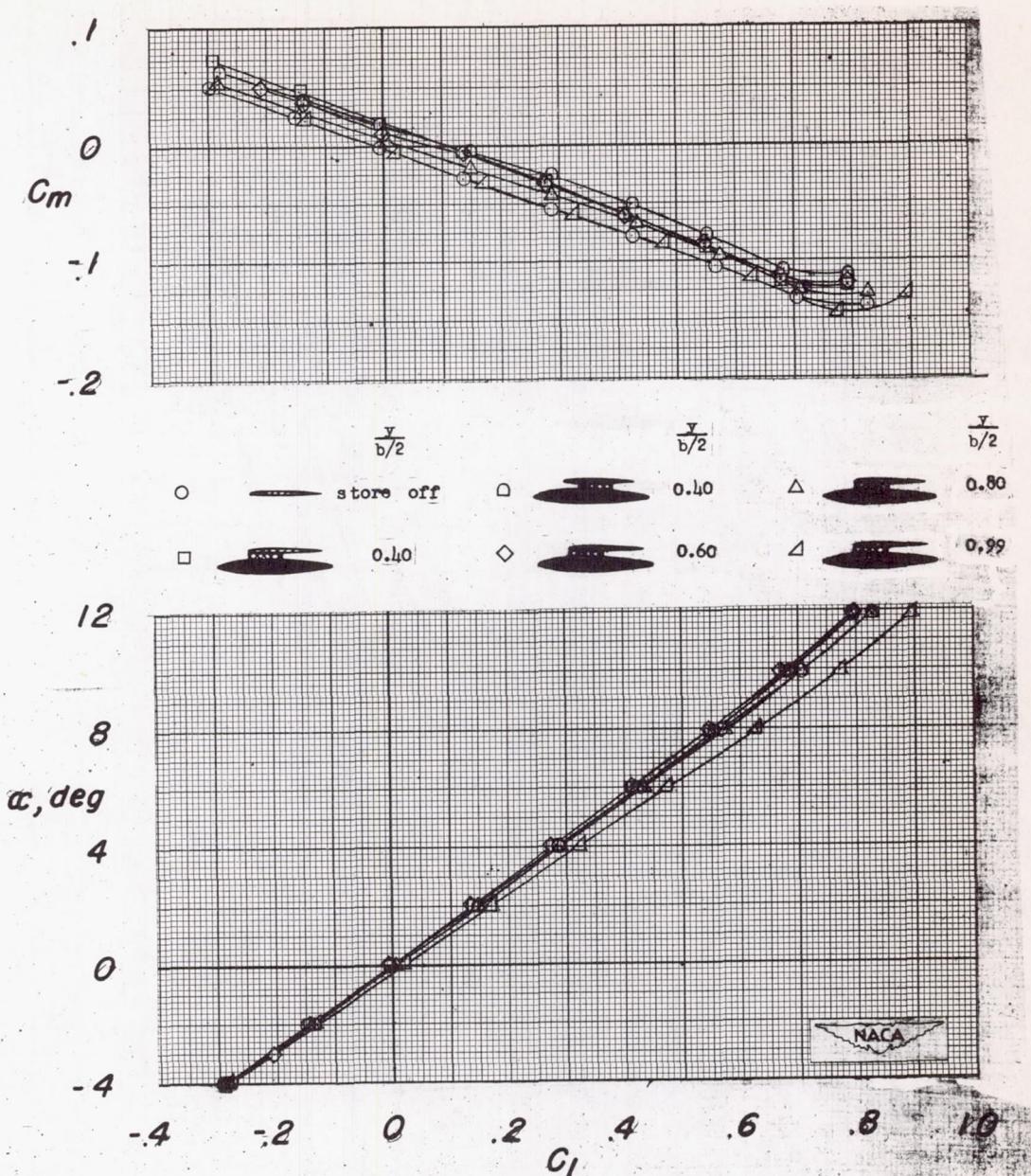
(a) C_m and α against C_L .

Figure 5.- Aerodynamic characteristics of an unswept semispan wing of aspect ratio 4 with DAC store with basic strut at various spanwise locations and with one strut at a midchord location. $M = 1.41$; $R \approx 1.4 \times 10^6$; $\frac{z}{d} = 1.0$.

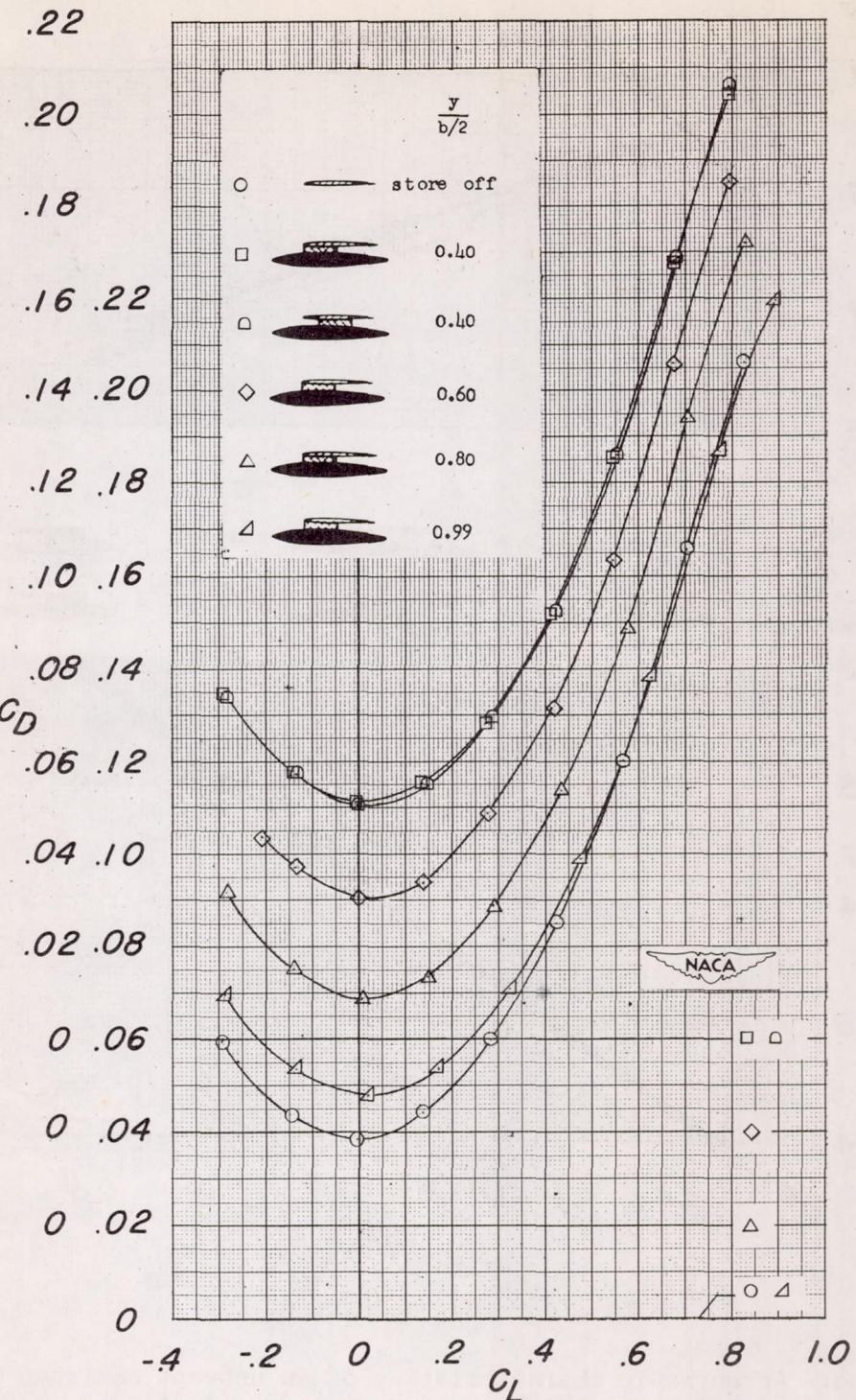
(b) C_D against C_L .

Figure 5.- Concluded.

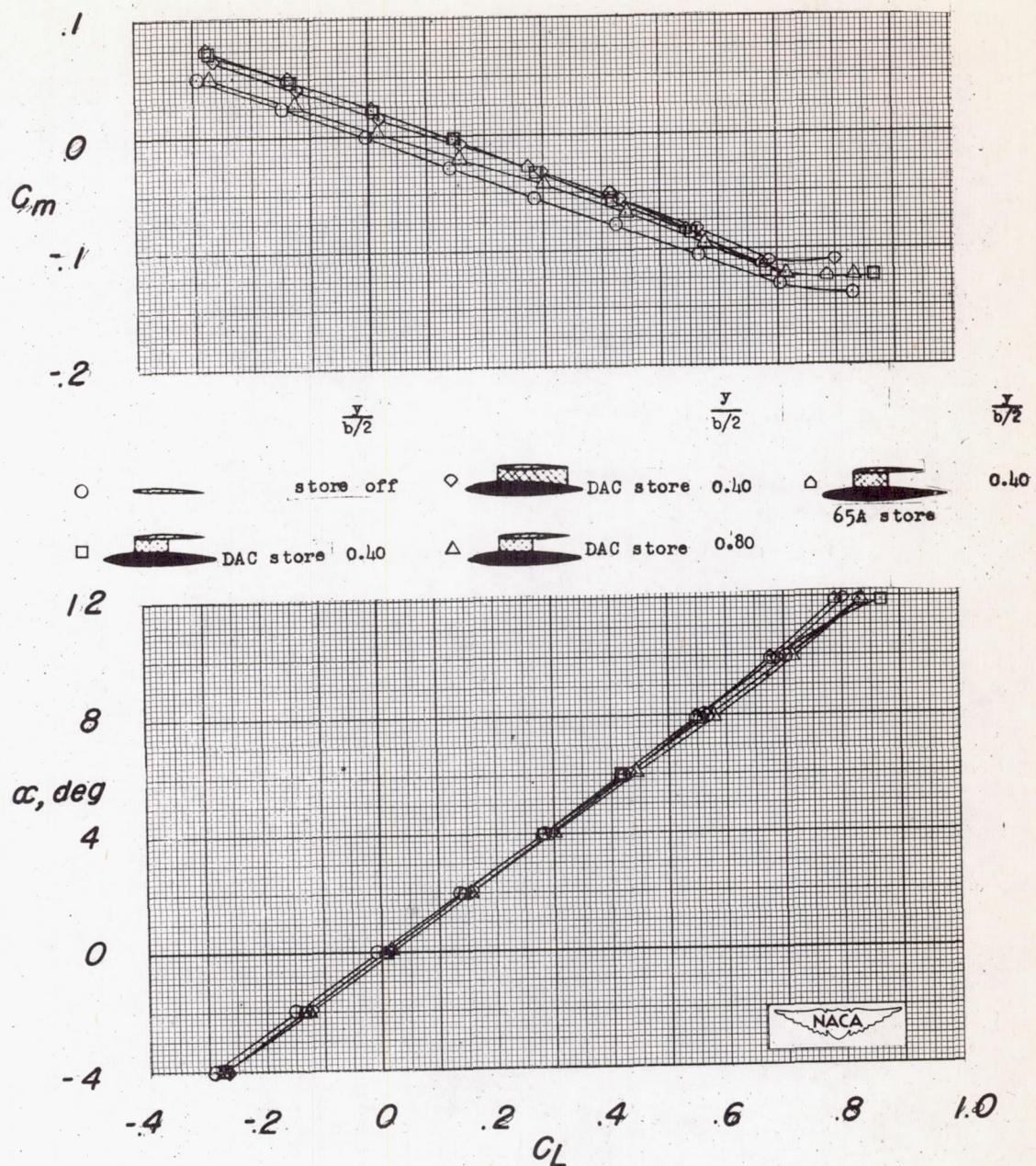
(a) C_m and α against C_L .

Figure 6.- Aerodynamic characteristics of an unswept semispan wing of aspect ratio 4 with DAC store with basic strut at various spanwise locations, with DAC store with a full chord strut, and with an NACA 65A-series body of revolution at one location. $M = 1.41$; $R \approx 1.4 \times 10^6$; $\frac{z}{d} = 1.5$.

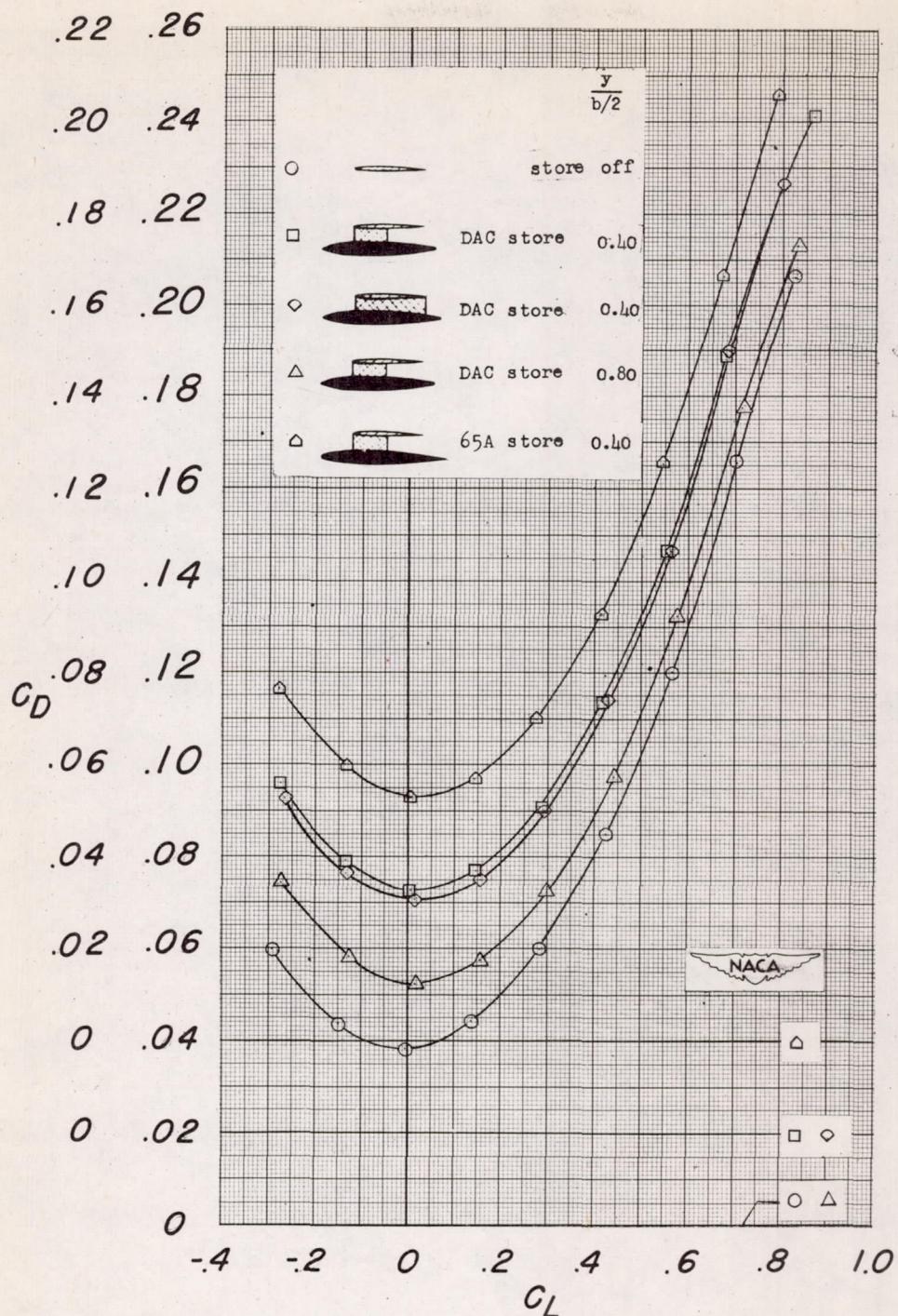
(b) C_D against C_L .

Figure 6.- Concluded.

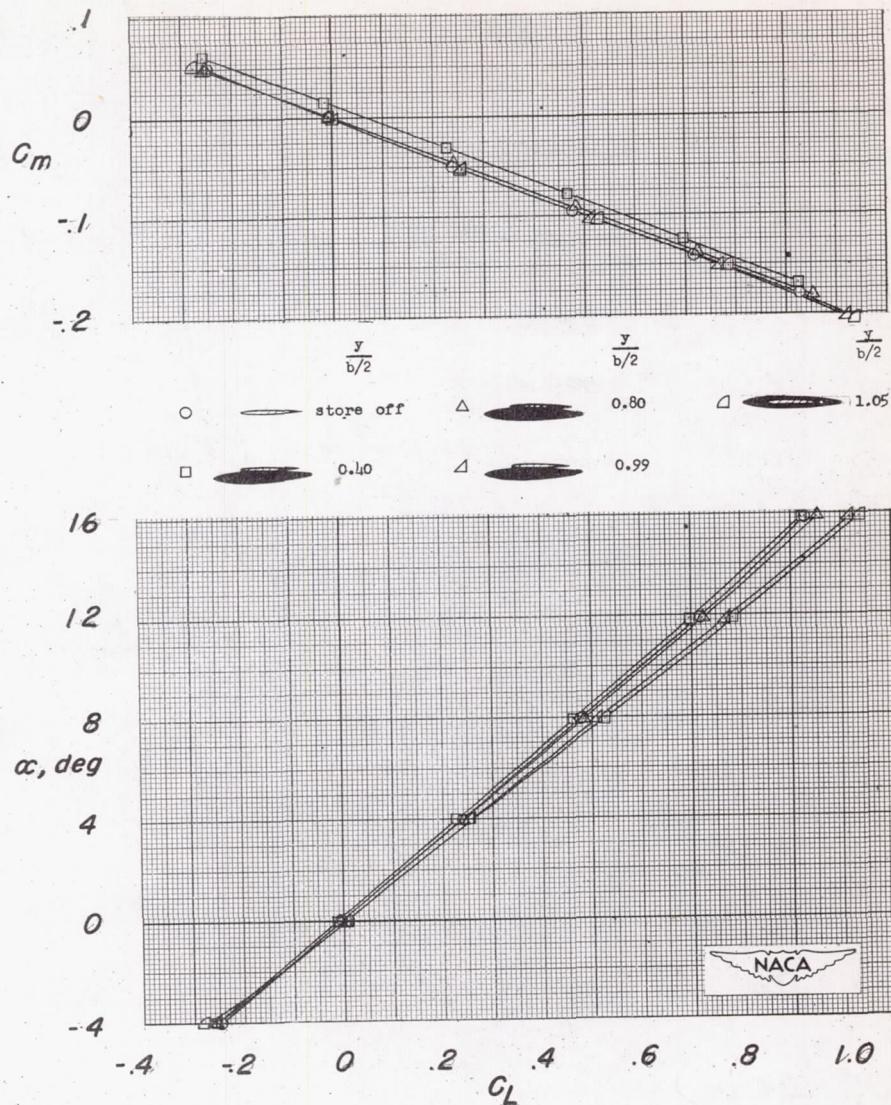
(a) C_m and α against C_L .

Figure 7.- Aerodynamic characteristics of an unswept semispan wing of aspect ratio 4 with DAC store with basic strut at various spanwise locations. $M = 1.62$; $R \approx 1.2 \times 10^6$; $\frac{z}{d} = 0$ and 0.5 .

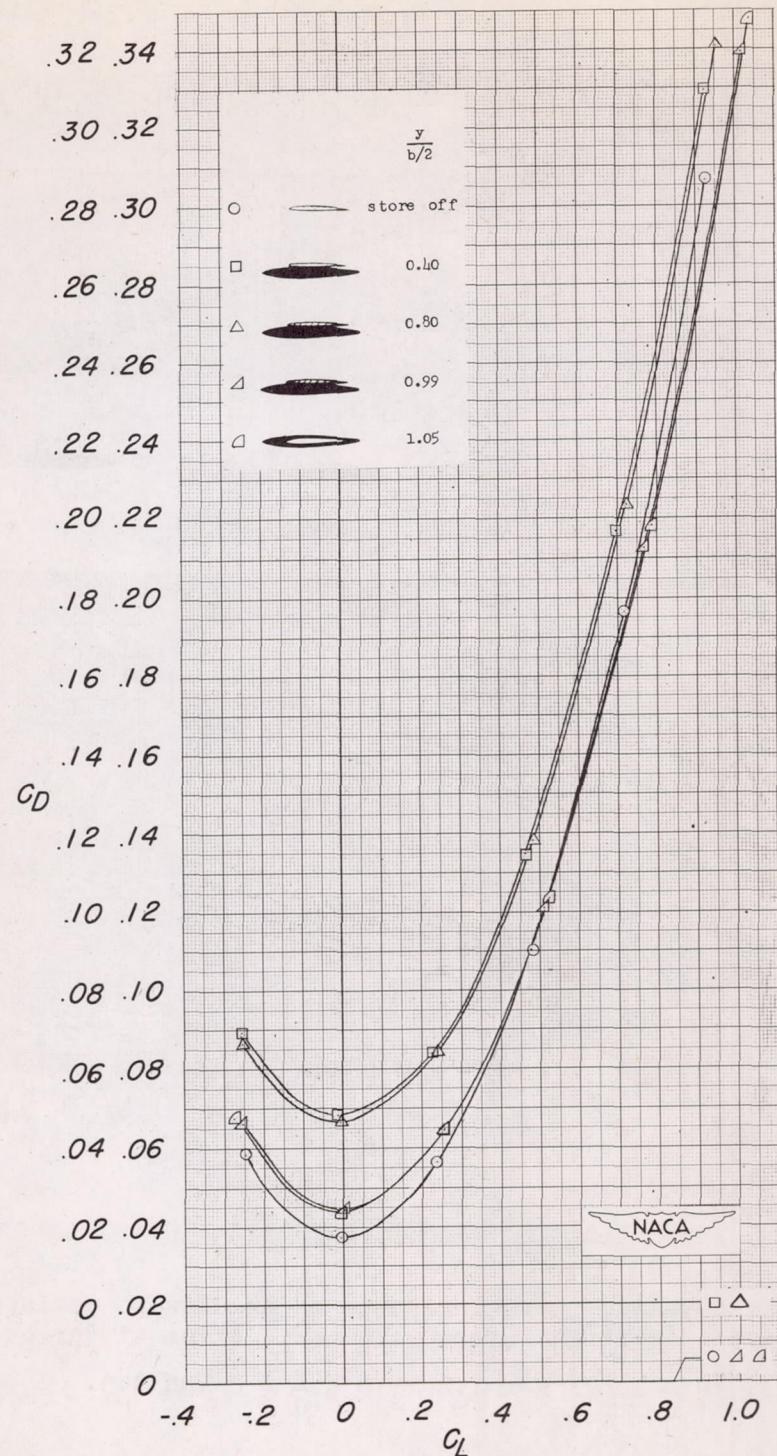
(b) C_D against C_L .

Figure 7.- Concluded.

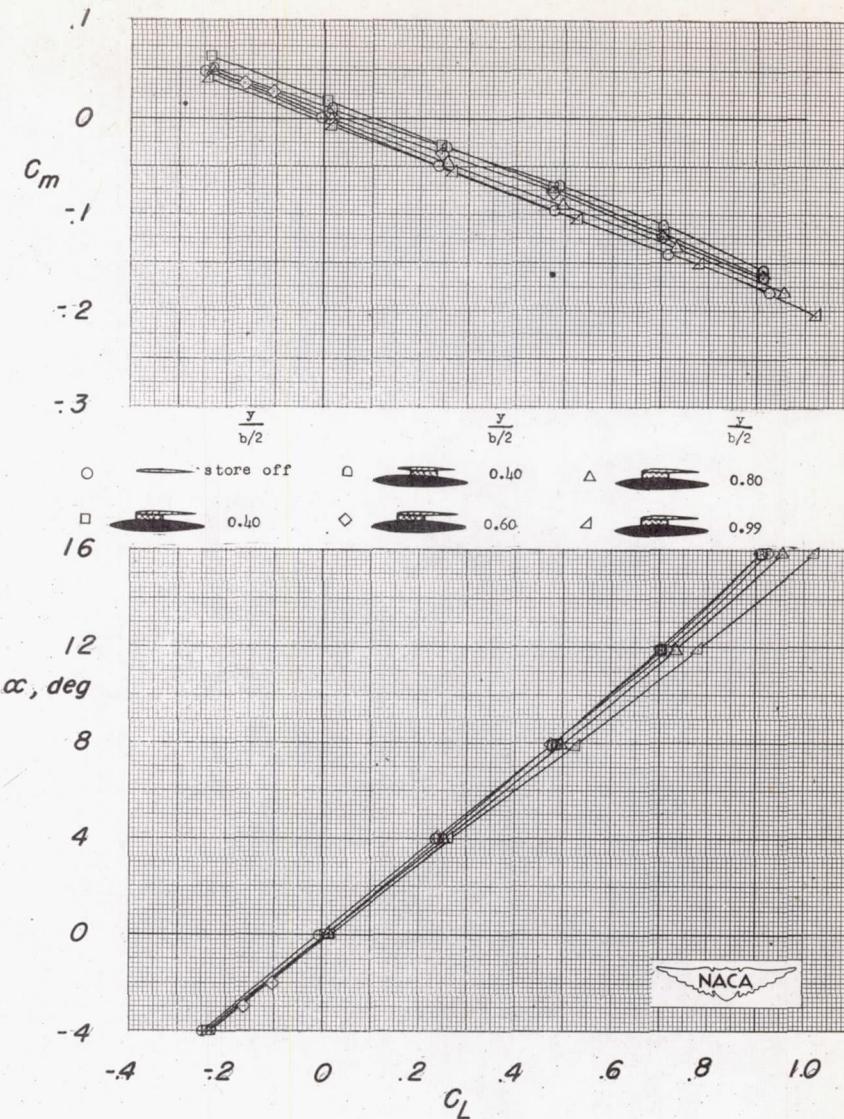
(a) C_m and α against C_L .

Figure 8.- Aerodynamic characteristics of an unswept semispan wing of aspect ratio 4 with DAC store with basic strut at various spanwise locations and with one strut at a midchord location. $M = 1.62$; $R \approx 1.2 \times 10^6$; $\frac{z}{d} = 1.0$.

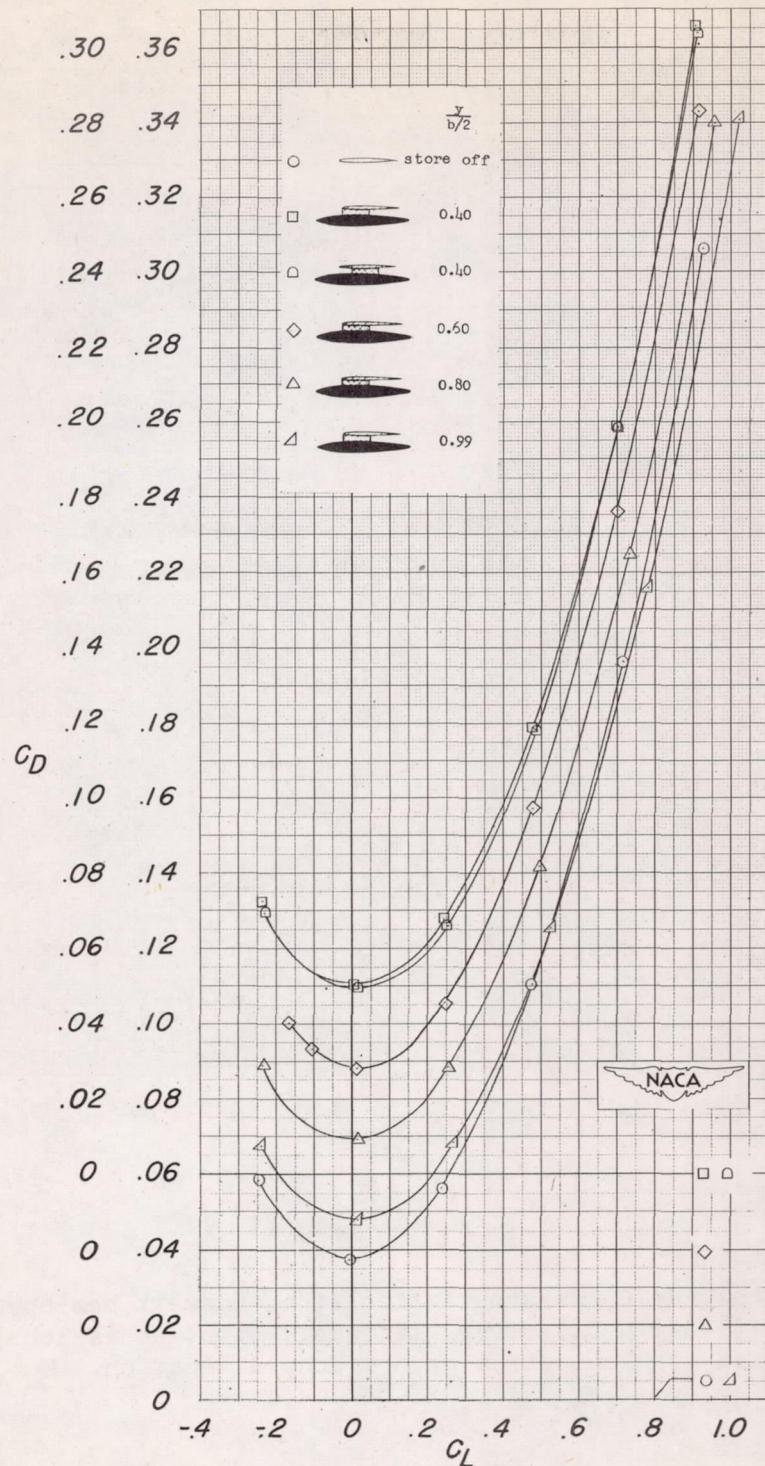
(b) C_D against C_L .

Figure 8.- Concluded.

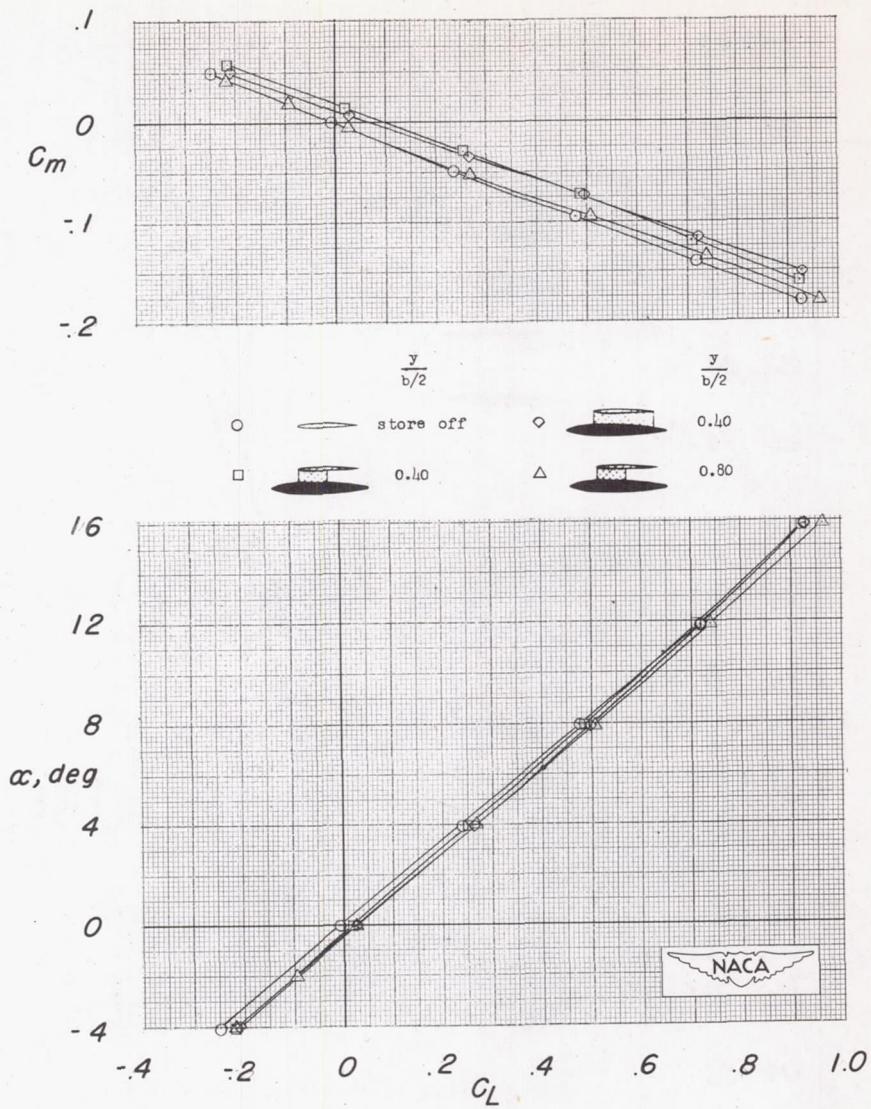
(a) C_m and α against C_L .

Figure 9.- Aerodynamic characteristics of an unswept semispan wing of aspect ratio 4 with DAC store with basic strut at various spanwise locations and with a full-chord strut. $M = 1.62$; $R \approx 1.2 \times 10^6$; $\frac{z}{d} = 1.5$.

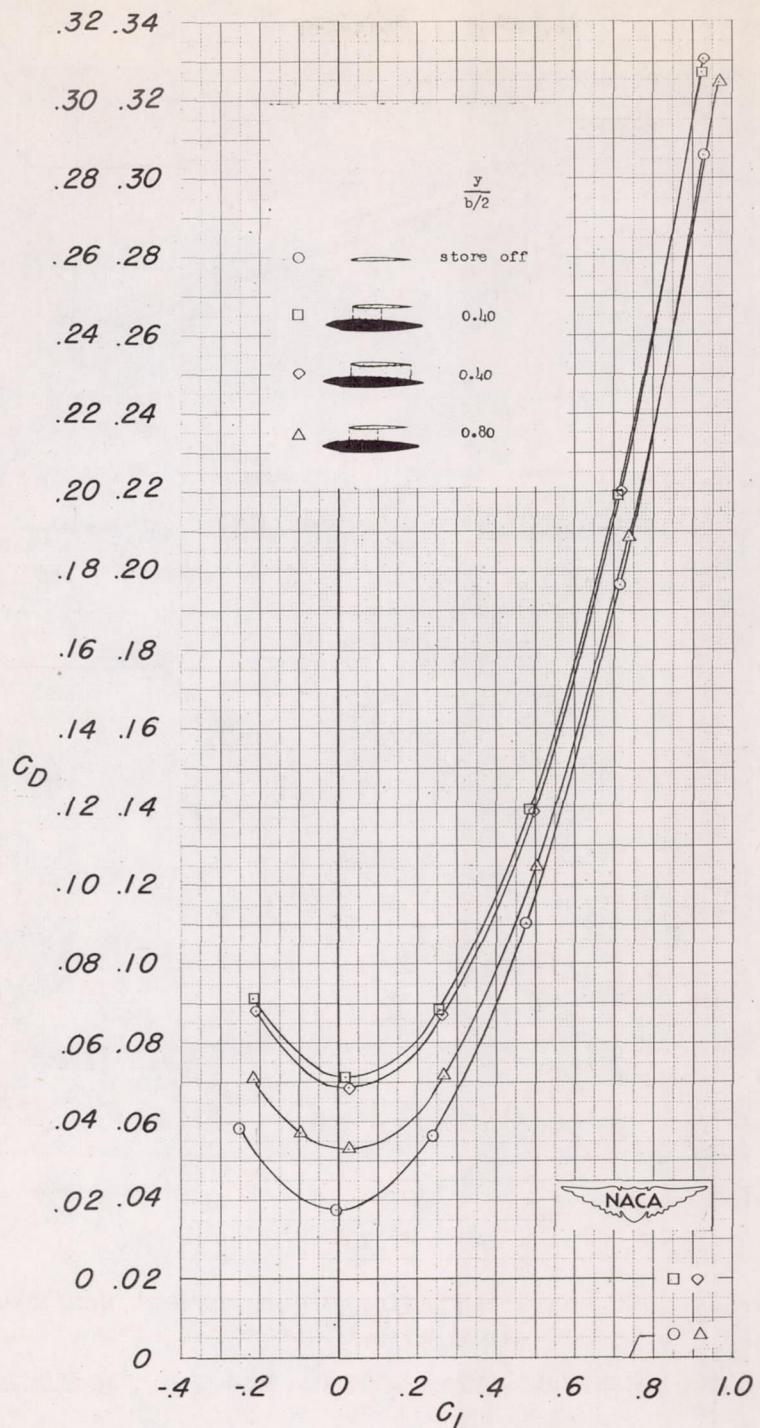
(b) C_D against C_L .

Figure 9.- Concluded.

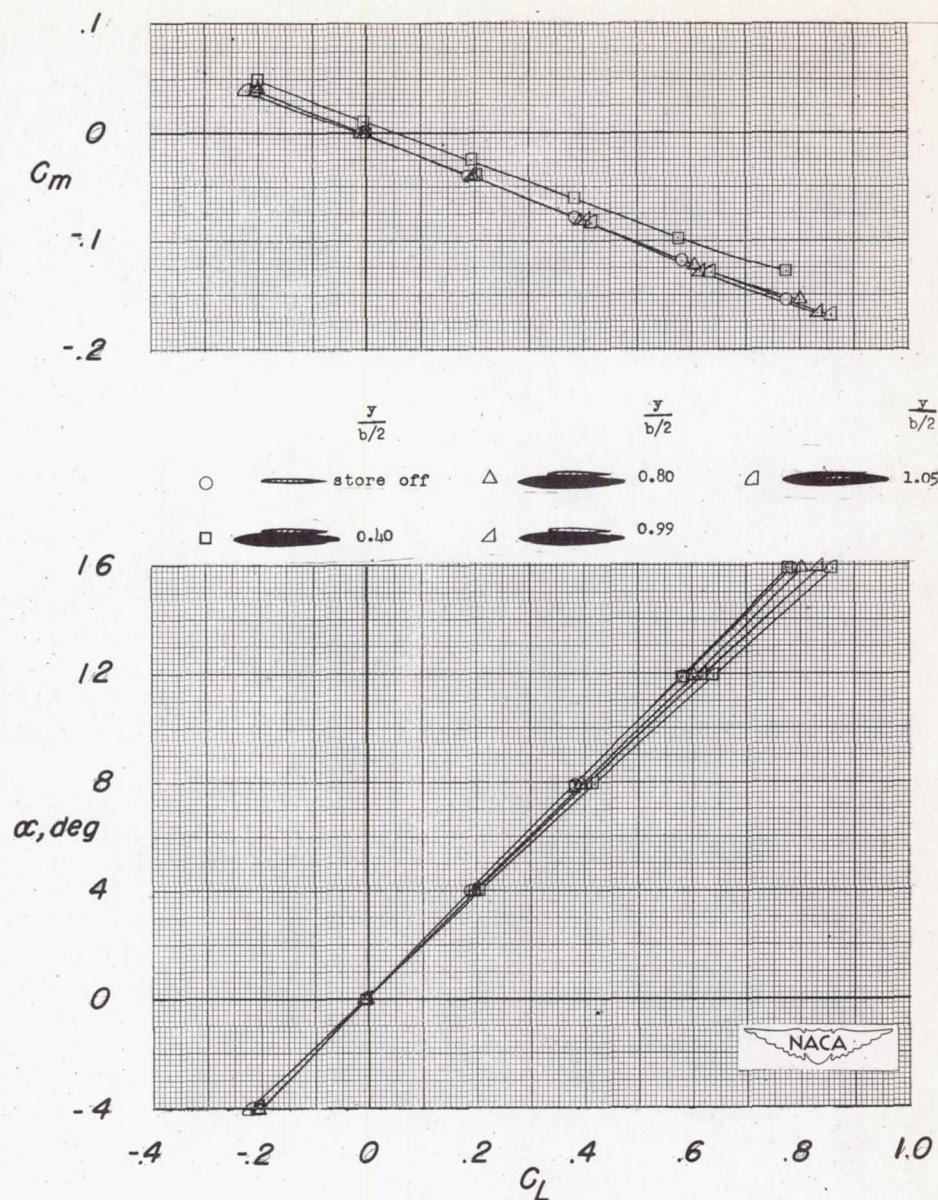
(a) C_m and α against C_L .

Figure 10.- Aerodynamic characteristics of an unswept semispan wing of aspect ratio 4 with DAC store with basic strut at various spanwise locations. $M = 1.96$; $R \approx 1.1 \times 10^6$; $\frac{z}{d} = 0$ and 0.5 .

4K

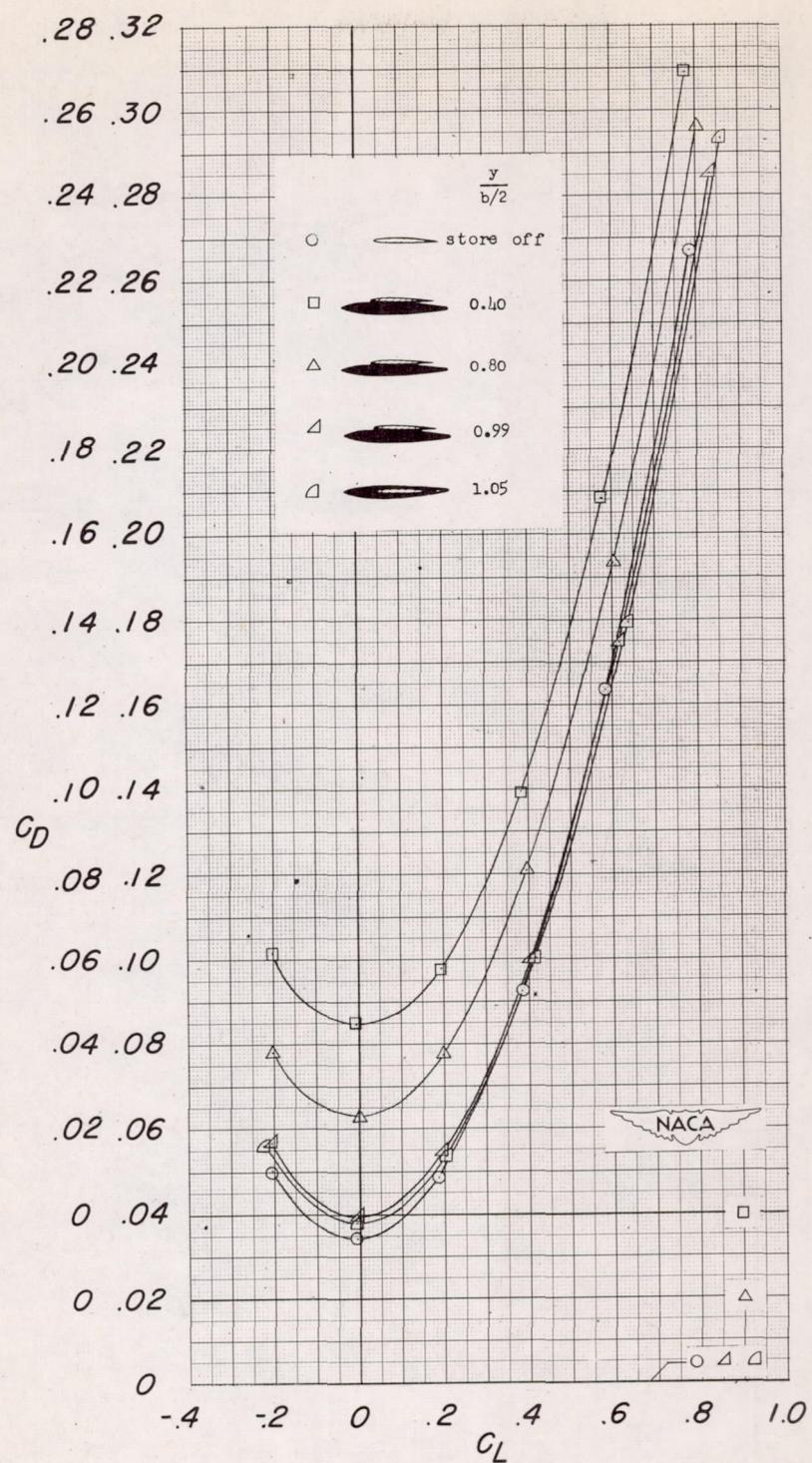
(b) C_D against C_L .

Figure 10.- Concluded.

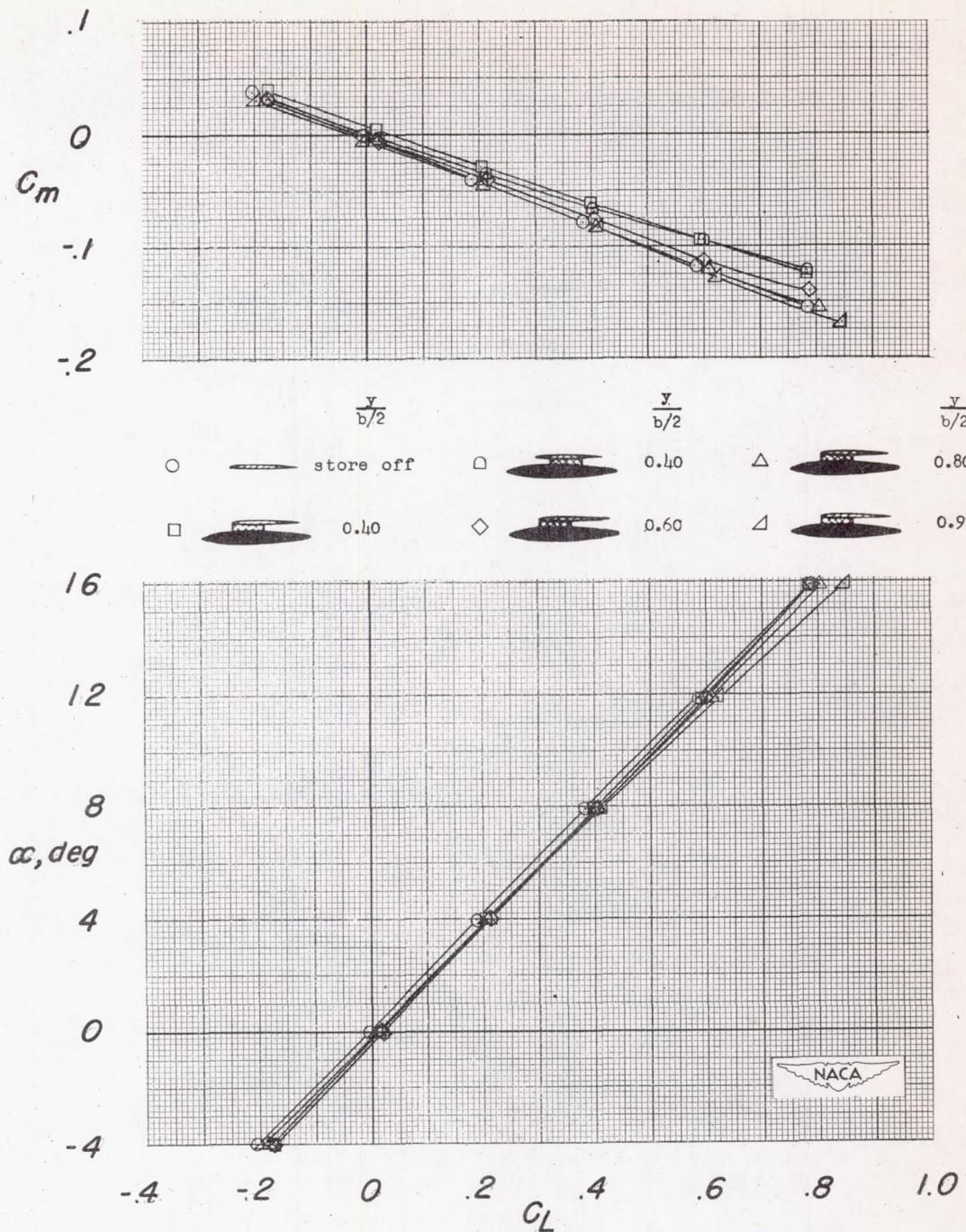
(a) C_m and α against C_L .

Figure 11.- Aerodynamic characteristics of an unswept semispan wing of aspect ratio 4 with DAC store with basic strut at various spanwise locations and with one strut at a midchord location. $M = 1.96$;
 $R \approx 1.1 \times 10^6$; $\frac{z}{d} = 1.0$.

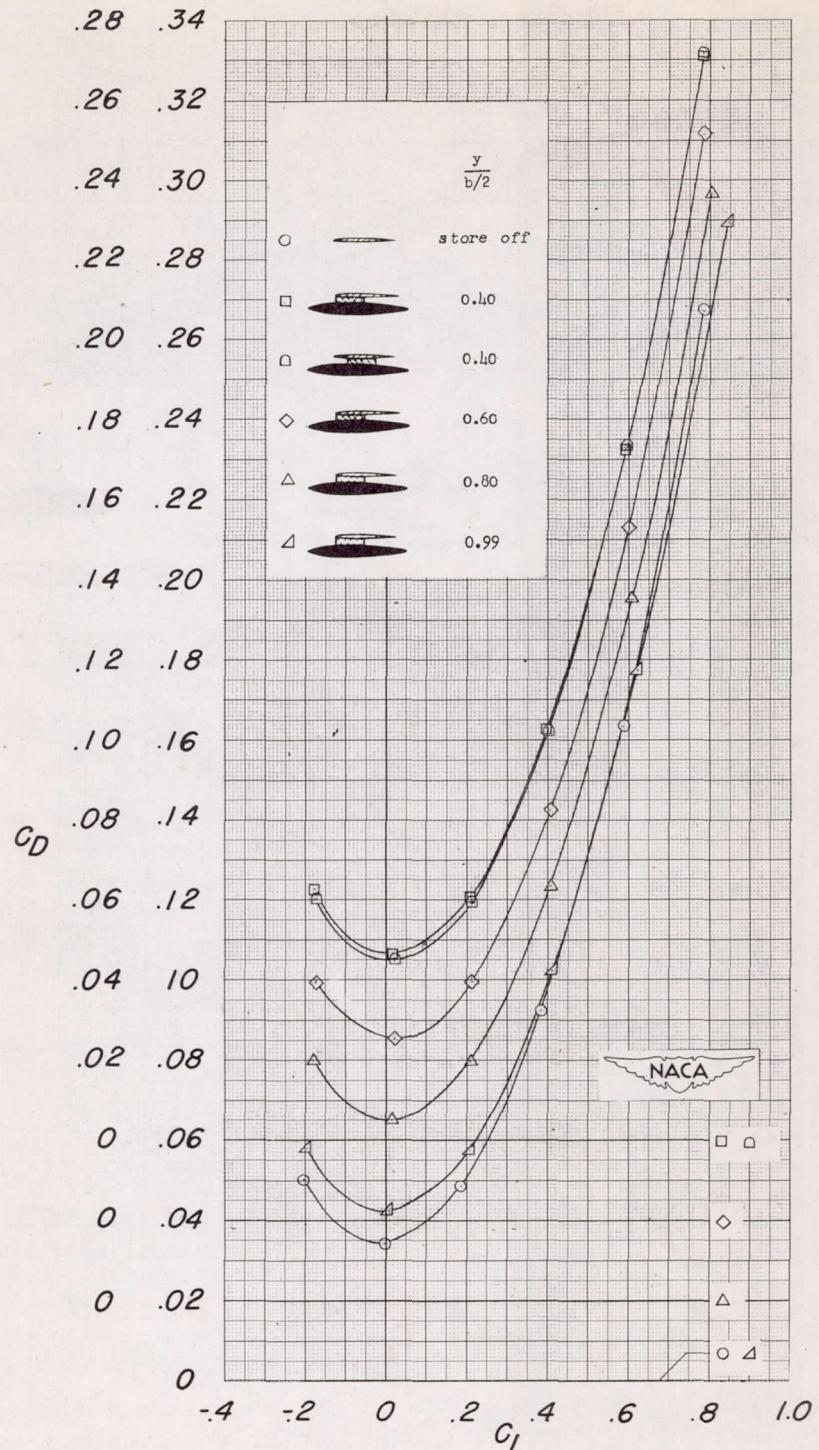
(b) C_D against C_L .

Figure 11.- Concluded.

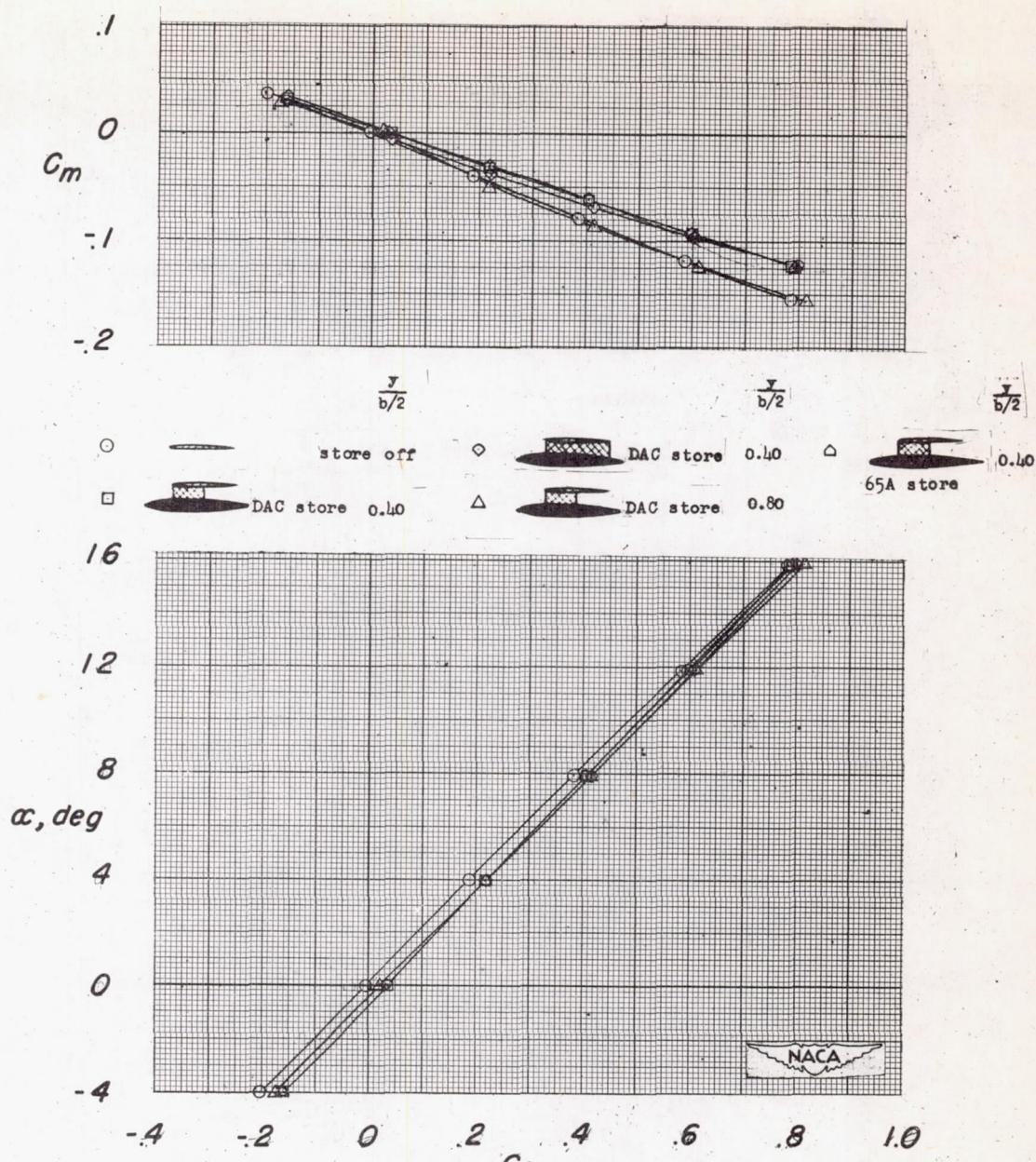
(a) C_m and α against C_L .

Figure 12.- Aerodynamic characteristics of an unswept semispan wing of aspect ratio 4 with DAC store with basic strut at various spanwise locations, with DAC store with a full-chord strut, and with an NACA 65A-series body of revolution at one location. $M = 1.96$; $R \approx 1.1 \times 10^6$; $\frac{z}{d} = 1.5$.

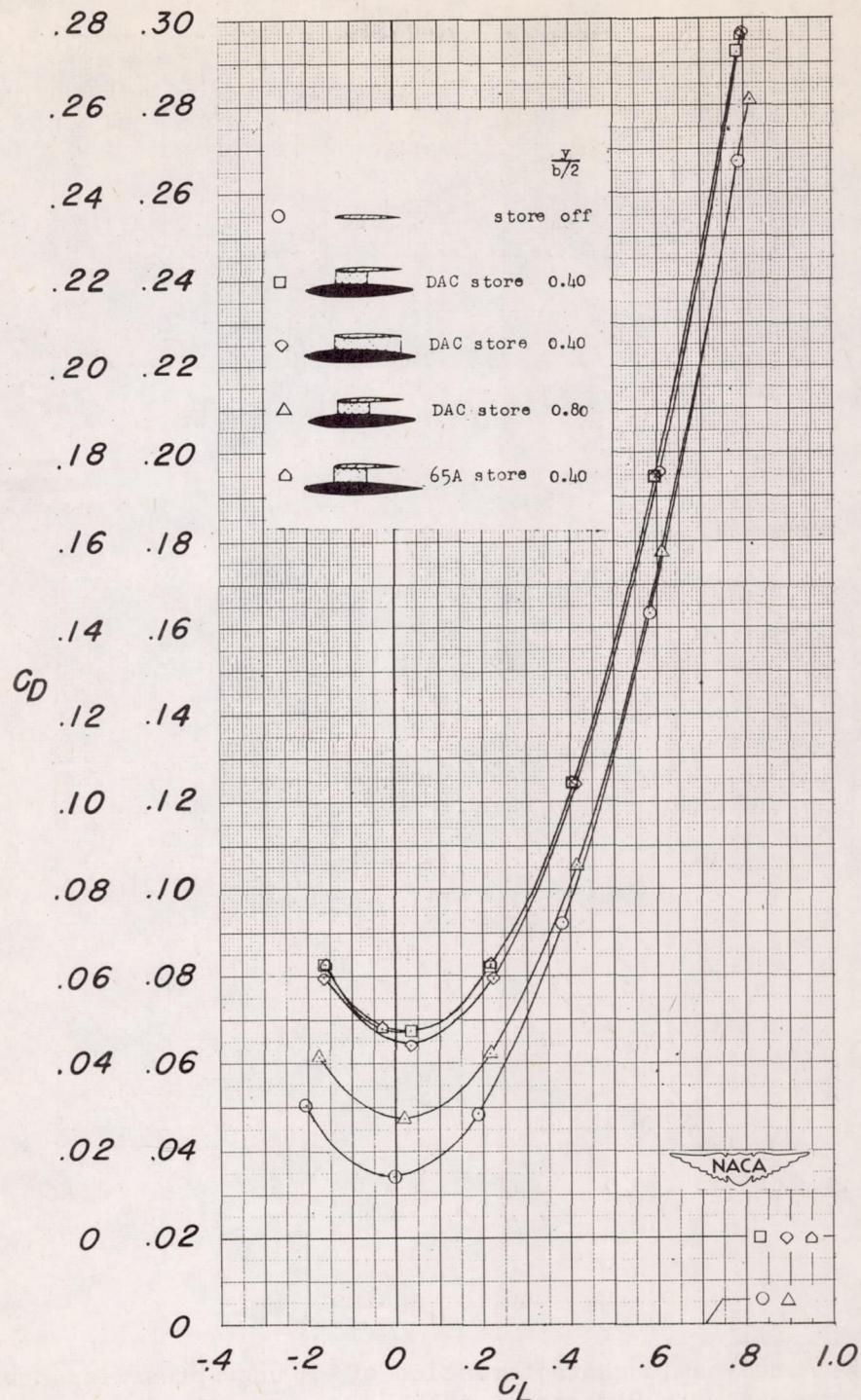
(b) C_D against C_L .

Figure 12.- Concluded.

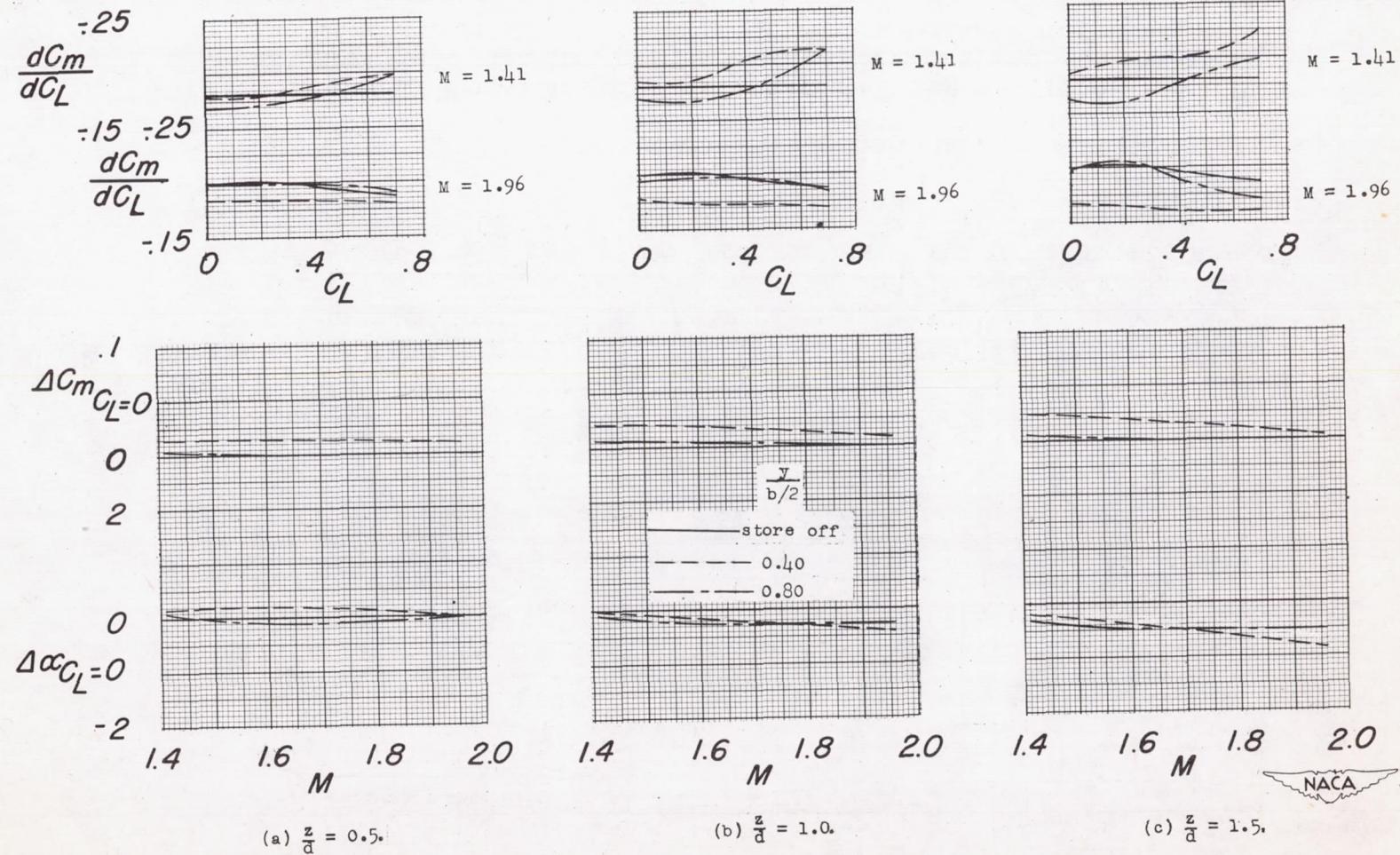


Figure 13.- Effects of DAC store on wing $\frac{dC_m}{dC_L}$ and on ΔC_m and $\Delta\alpha$ at zero lift.

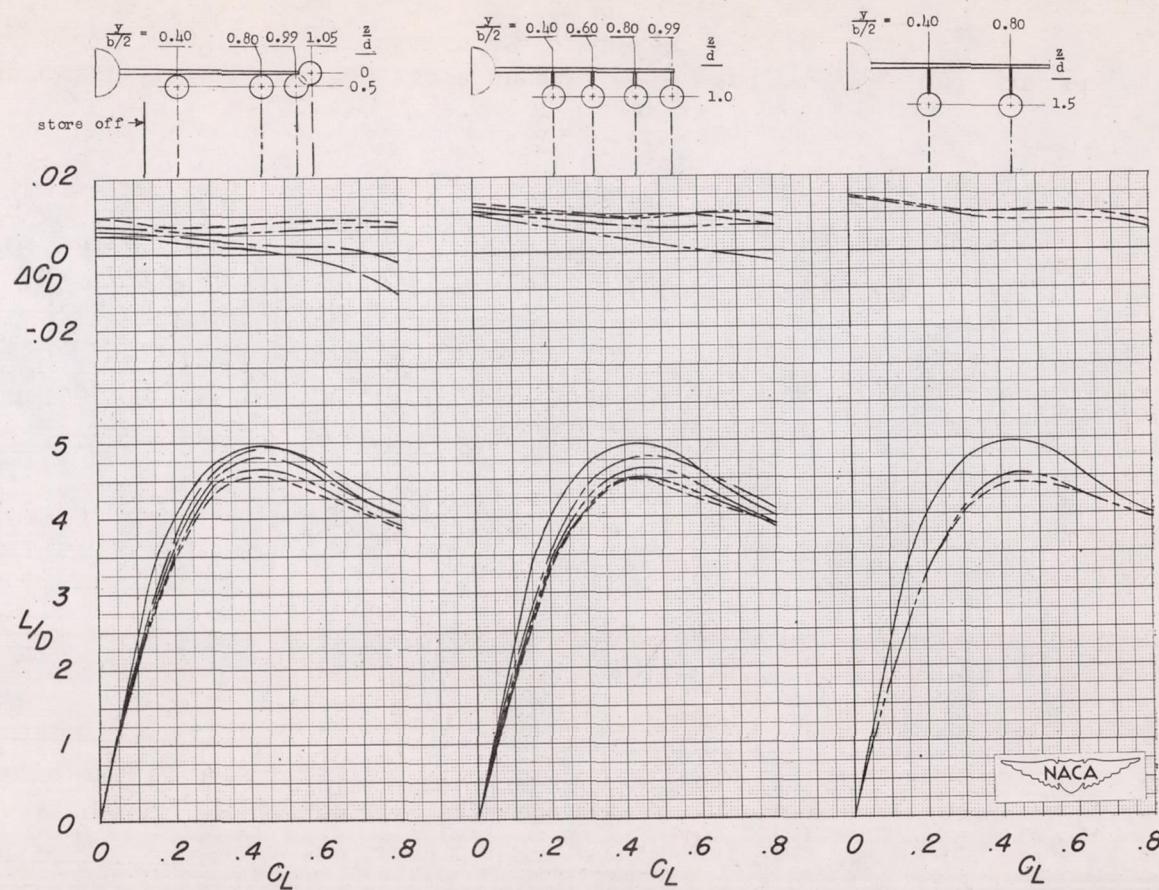
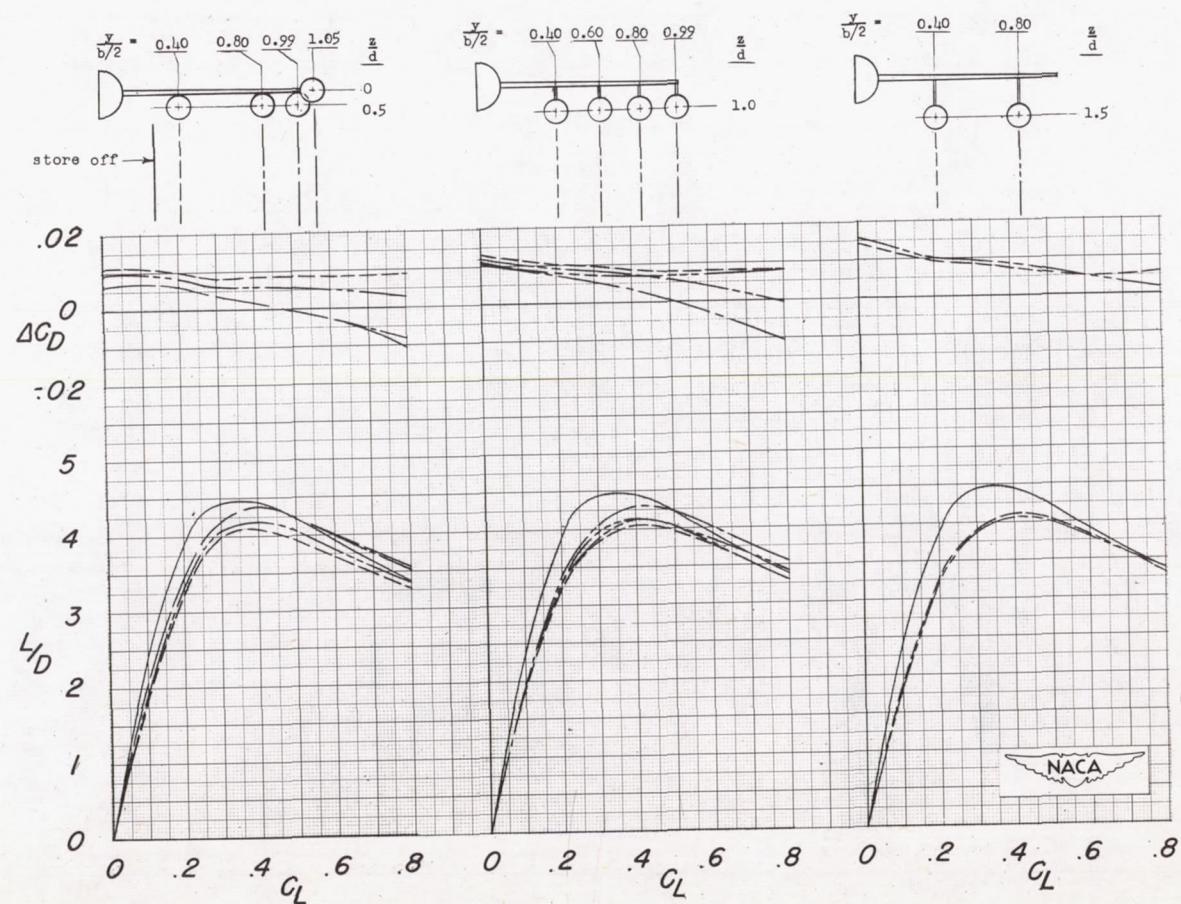
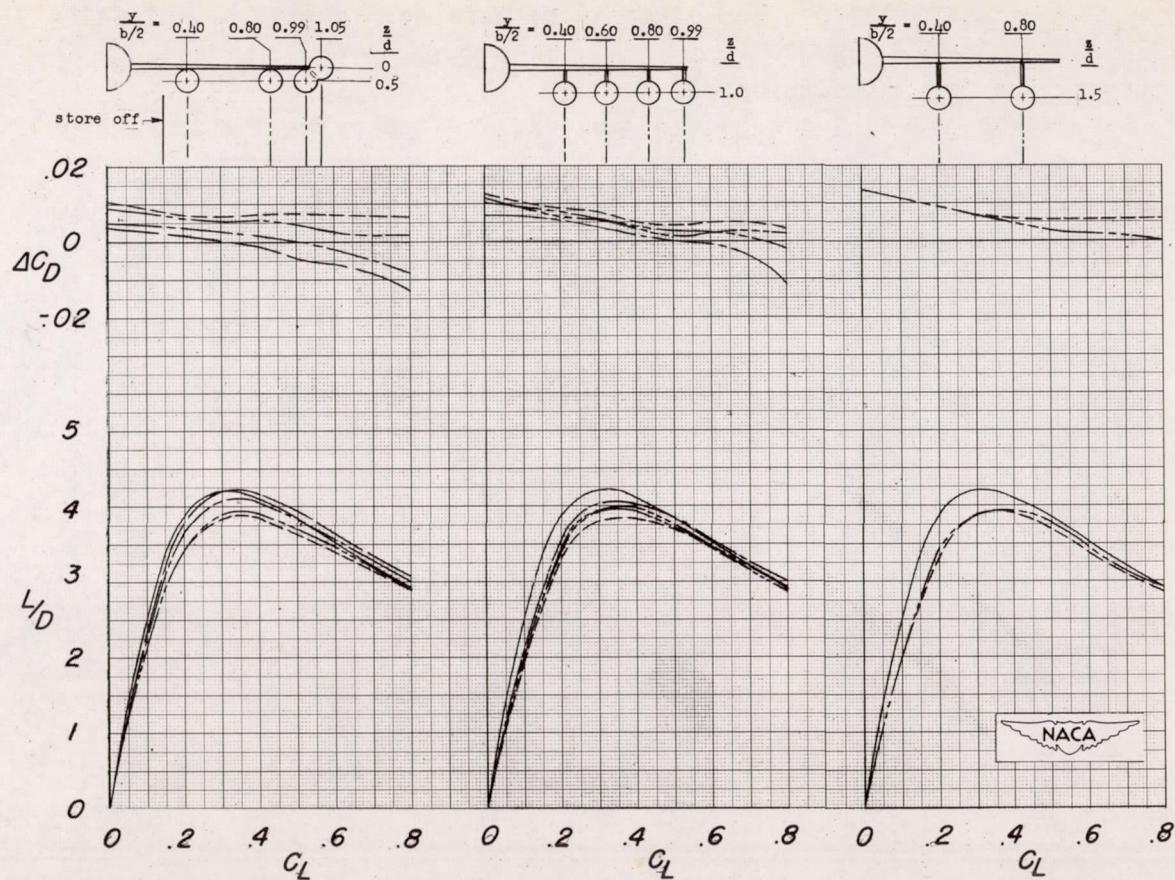
(a) $M = 1.41$; $R \approx 1.4 \times 10^6$.

Figure 14.- Variations of store incremental drag coefficient and lift-drag ratio with lift coefficient for various spanwise and vertical locations of the DAC store on an unswept semispan wing of aspect ratio 4.



(b) $M = 1.62; R \approx 1.2 \times 10^6$.

Figure 14.- Continued.



(c) $M = 1.96$; $R \approx 1.1 \times 10^6$.

Figure 14.- Concluded.

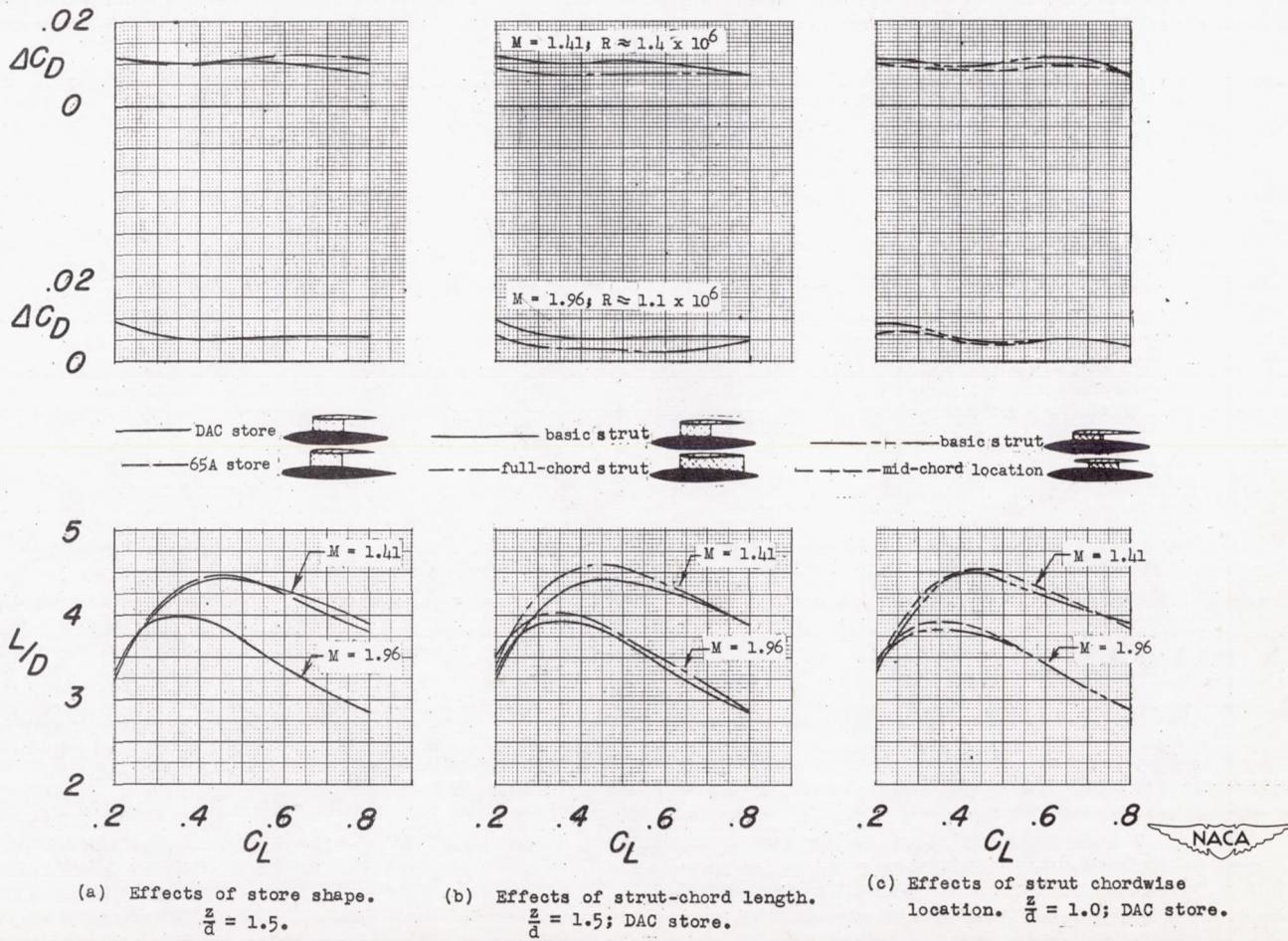


Figure 15.- Effects of varying store shape, strut-chord length, and strut chordwise location on the store incremental drag coefficient and on the lift-drag ratio of an unswept semispan wing of aspect ratio 4. All stores were located at $\frac{y}{b/2} = 0.40$.